METAL PROGRESS

JUNE 1950

THIS ISSUE

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Nominations for National Officers of A. S. M.

IN CONFORMITY with Article IX of the Constitution of the American Society for Metals, the duly accredited nominating committee met in Cincinnati, Ohio, on May 22 and made the following nominations for national officers of the Society:

WALTER E. JOMINY, for President for one year.

JOHN CHIPMAN, for Vice-President for one year.

J. B. AUSTIN (New York Chapter) for Trustee for two years.

JAMES T. MACKENZIE (Birmingham Chapter) for Trustee for two years.

Also, according to the Constitution, Article IX, the committee for nominating a secretary was composed of the president (Arthur E. Focke), chairman, and the six persons who most recently held the office of president, namely, H. K. Work, F. B. Foley, A. L. Boegehold, C. H. Herty, Jr., K. R. Van Horn, and M. A. Grossmann. This committee has made the following nomination:

WILLIAM H. EISENMAN, for Secretary for two years.

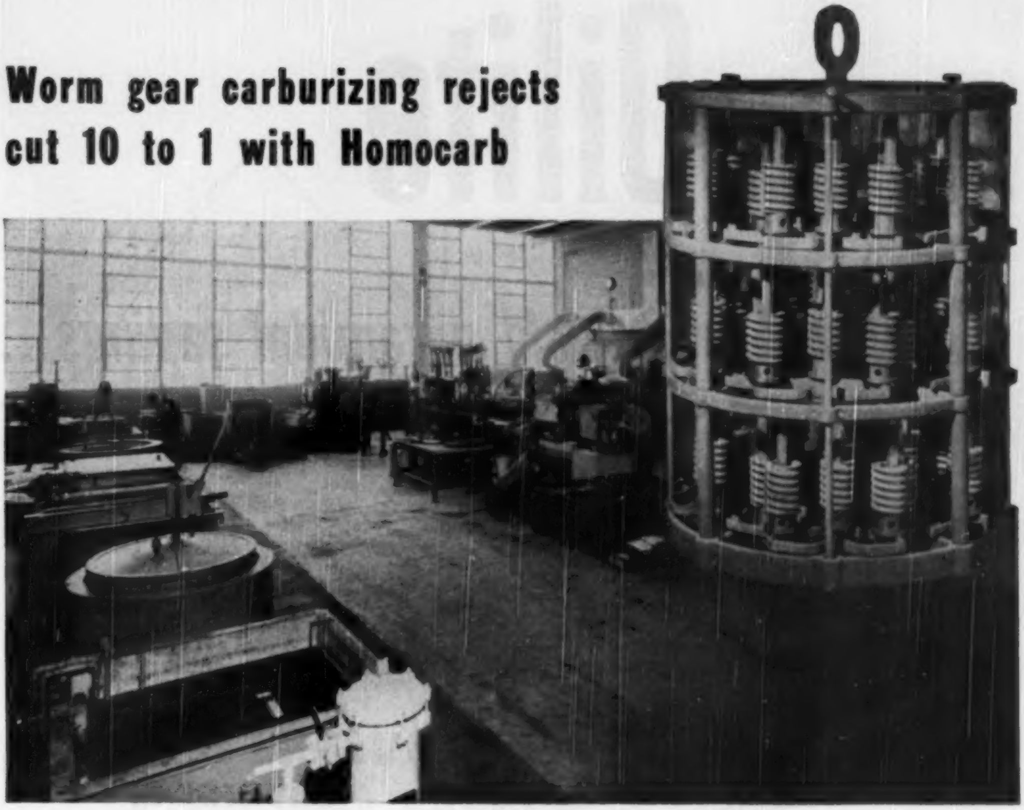
Article IX on the nomination, election and term of officers also contains the following:

Section 1 *(c)* **Additional Nominations.** After publication of the names of the candidates nominated by the Nominating Committee and by the Committee for Nomination of a Secretary for the Society, if any, and at any time prior to July 15th of the same year, additional nominations for any or all the vacancies may be made by written communications addressed to the Secretary of the Society and signed by any fifty (50) members and/or representatives of member firms or corporations.

(d) **Voting at Annual Meetings.** If no such additional nominations are received prior to July 15th, nominations shall be closed and the Secretary, at the next succeeding annual meeting of the members, shall cast the unanimous vote of all members for the election of the candidates so nominated.


When considering Induction Heating Equipment for Hardening, Brazing, Soldering, Annealing, Forging, or Melting—
remember
TOCCO
OFFERS
Both
TUBE OSCILLATORS
for radio frequencies, nominally 450,000 cycles per second.
MOTOR GENERATORS
for frequencies up to 10,000 cycles per second.

Worm gear carburizing rejects cut 10 to 1 with Homocarb



CROWN Cork and Seal Company, Baltimore (whose heat-treat is shown above), cut rejects on their carburized machine parts 90% by switching to the L&N Homocarb method of carburizing. This famous company, whose products go to brewers, dairies and soft-drink makers, formerly used the pack carburizing method but changed over when their new plant was built. In addition to drastically reducing the number of rejected parts, handling time was greatly decreased and the whole operation made part of a fast, clean, efficient heat treating production line.

Homocarb handles variety of parts

Typical parts requiring carburizing are transmission worms (shown above), cylinder guide rollers, sprocket and drive gears. Steels range from SAE 1320 cold drawn to 4615 nickel. The carburizing must be deep and uniform, to permit close Rockwell C limits after tempering.

Each load almost half a ton

Heat treating these parts on a mass production basis starts at the large Homocarb furnace. A typical furnace batch is between 800 and 900 pounds. Work is brought up to 1700F smoothly and evenly, in 3½ hours. Parts are carburized there for four hours. Following carburization, parts are furnace cooled to between 1400 and 1500F under the protection of the Homocarb atmosphere. The built-in Homocarb convection cooler makes it possible to bring the parts to the desired temperature in about a fourth of the time needed for normal radiation cooling. Actual final cooling temperature is determined by the quench, either oil or 10% brine. After quenching, the entire load is thoroughly cleaned and loaded into an L&N Homo furnace for tempering. The parts are air cooled to finish the tempering operation, then coated with anti-rust and shipped to other departments of the plant.

Heat treater always controls process

The Homocarb method is a complete process for carburizing or gas cyaniding practically any steel part. Homocarb assures accurate, quality work because all four factors that affect the carburizing cycle are under control of the heat treater at all times. Thus, each part is heated to the same temperature, in the same quality and quantity of carburizing gas, and for the same length of time. Because of this identical treatment, the heat treater can duplicate his results time and time again. For further information write to Leeds & Northrup Company, 4927 Stenton Avenue, Philadelphia 44, Pa.

LEEDS & NORTHRUP

Jrl. Ad TD4-623(1)

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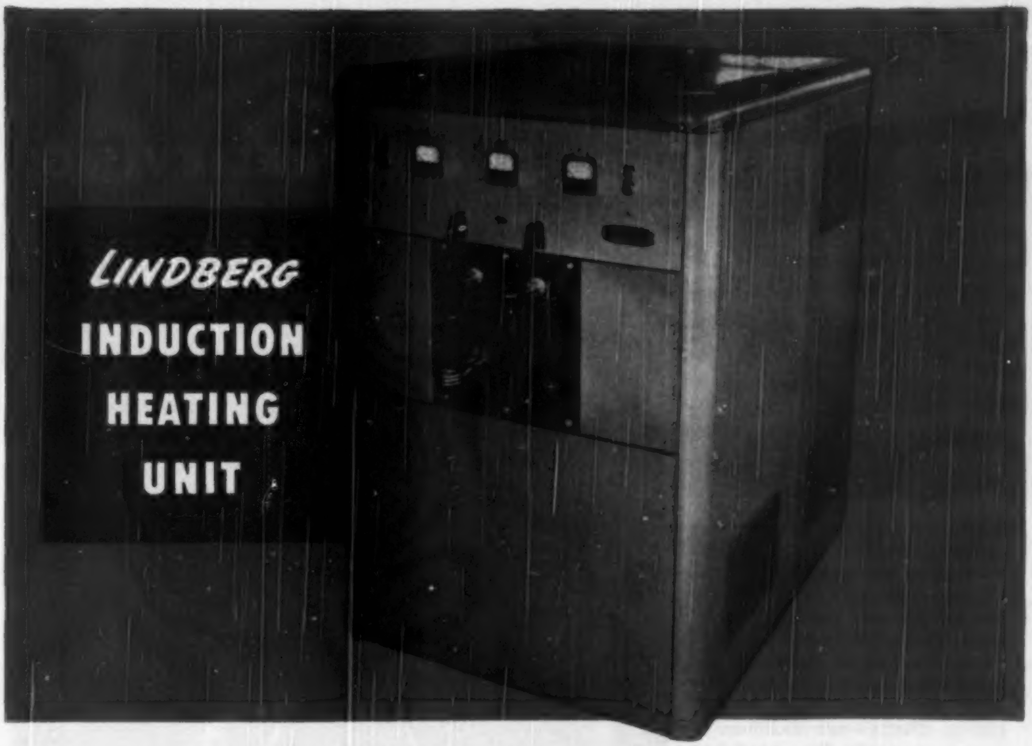

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Available in single and two-station models the Lindberg LI-25 is ideal for hardening, brazing and soldering, annealing and stress relieving, hot forming and light forging, shrink fitting and other induction heating applications.

The Lindberg LI-25 is a ruggedly constructed vacuum-tube type unit for hard working production line jobs. Oscillator tube, power transformer and other major components deliver a full 25 KW with plenty of reserve to insure dependable day in and day out performance. Well designed—safe and simple to operate—featuring the most desirable developments in high frequency heating.

CONDITIONED COOLING—Built-in to increase tube life, eliminate harmful condensation and scaling, reduce water pressure and consumption —can be used with hard water. Rubber hoses are completely eliminated.

"CHECKLITE"—a unique feature exclusive with this unit, makes servicing easier, reduces maintenance costs.

AUTOMATIC CONTROL—when job cycles are set, automatic timer controls every phase of the operation—heat, quench, fixture movement.

SAFE AND SIMPLE—both operator and operating parts are protected—filament voltages are constantly regulated—tank capacitor is hermetically sealed—work coils protected against burn out. Every unit certified to meet FCC regulations. For detailed information write for Bulletin T-1420.

For specific application information contact your local Lindberg Office, or write describing your problem in detail.

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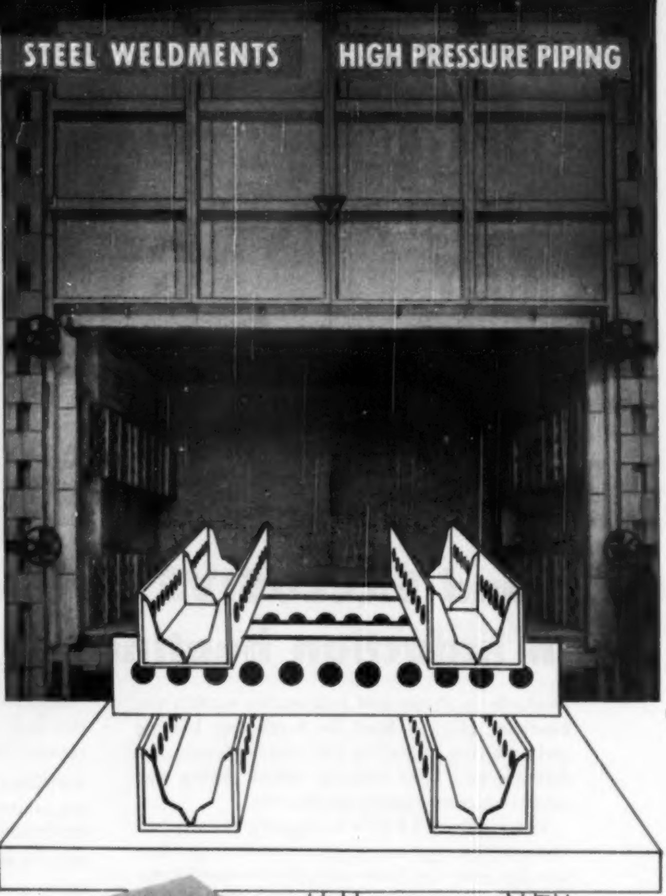
ALUMINUM ASSEMBLIES | **STEEL WELDMENTS** | **HIGH PRESSURE PIPING**

Recirculating Type Car Bottom

FURNACE

built and installed at Bath Iron Works, Bath, Maine by

DESPATCH



Designed for close temperature cycle control and uniform heat throughout the work chamber, this Despatch built large batch type furnace provides the highest efficiency in solution heat treating and stress relieving of aluminum gun foundations, and stress relieving of steel weldments and high pressure piping. Temperature maximum of the unit is 1350°F. Two 3,000,000 BTU per hour oil heaters furnish ample heat and special high volume fans transfer heat at great velocity throughout the work chamber to achieve the required uniformity. The furnace has automatic temperature controls and approved safety equipment.

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The car which forms the furnace floor has special heat sealing edges and is equipped with an electric car pull allowing a maximum speed of 20 ft. per minute. The lift door is also electrically operated.

Capacity for stress relieving steel weldments and high pressure piping is 12,000 lbs.; for aluminum gun foundations, 5,400 lbs. plus 2,000 lbs. of steel jigs and fixtures.

Working dimensions of the furnace are 18 ft. wide by 25 ft. long by 12 ft. high.

ASK DESPATCH

If you have a metal normalizing problem Despatch engineers can help you. We build all types and sizes of industrial furnaces. Despatch also designs, builds and installs foundry ovens, finish bake ovens or complete finishing systems to fit every production need. Call or write Despatch Today for further details.

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UNITED CARR FASTENER CUTS PLATING REJECTS AND PRODUCTION TIME

with the Du Pont

SODIUM HYDRIDE DESCALING PROCESS

Courtesy: United Carr Fastener

Loading perforated dip basket with closure buttons for immersion in sodium hydride descaling bath.

Since 1946, United Carr Fastener Corporation has used the Du Pont Sodium Hydride Descaling Bath in its Cambridge, Mass., plant for the thorough cleaning of intricately shaped steel objects prior to finishing. This efficient process which preserves base metal surfaces has enabled United Carr to maintain high dimensional accuracy on its fastener products. And plating rejects due to blistering have been eliminated!

Operator removing sodium brick to charge generator. Closure buttons in basket are ready for descaling.

Production time has been sharply cut, too. The bath has proved so efficient in removing scale from recesses and indentations not reached by other cleaning methods that parts are now cleaned in one-fourth the time formerly required. A net saving of 75% in acid cost has been realized along with a substantial reduction in spent acid disposal. In addition, subsequent polishing and burnishing operations have been reduced 50 to 75%.

Tempering of the work is now done simultaneously with descaling. The descaling equipment handles over 600 lbs. of work hourly. Accessory equipment includes a cyanide neutralizing tank to treat work which is not to be finished immediately.

United Carr Fastener's complete satisfaction with the Du Pont Sodium Hydride Descaling Process can be duplicated over and over again by many other plants. Why not investigate its possibilities for your own operations? Send the coupon below for your copy of the booklet "Du Pont Sodium Hydride Descaling Process." It describes the process and tells how it can mean important savings in metal, time, space, and materials in your plant.

Closure buttons are released into quench tank through hinged bottom of basket.

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DU PONT

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E. I. du Pont de Nemours & Co. (Inc.)
Electrochemicals Department
Wilmington 98, Delaware

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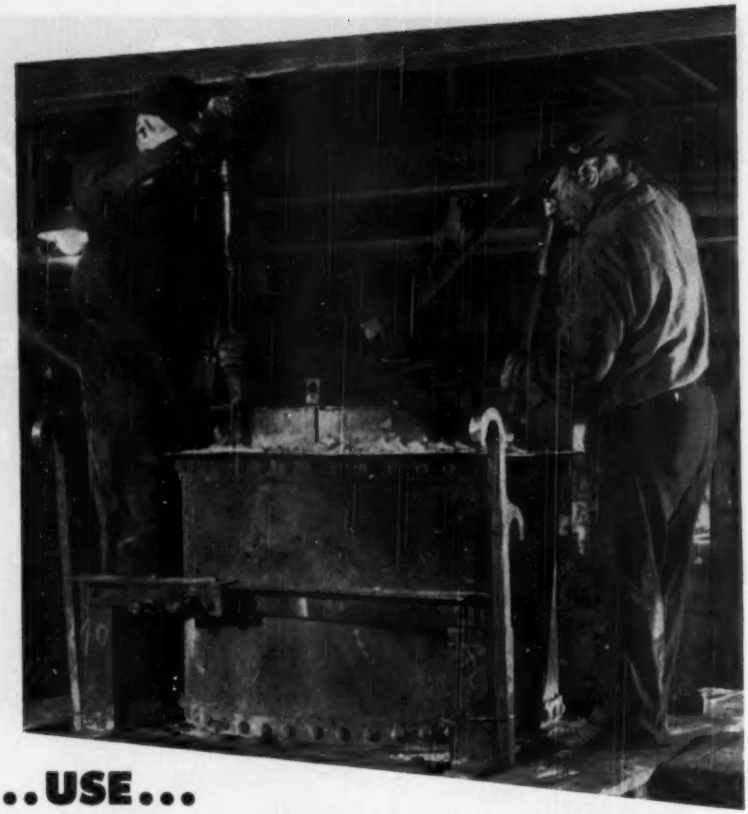

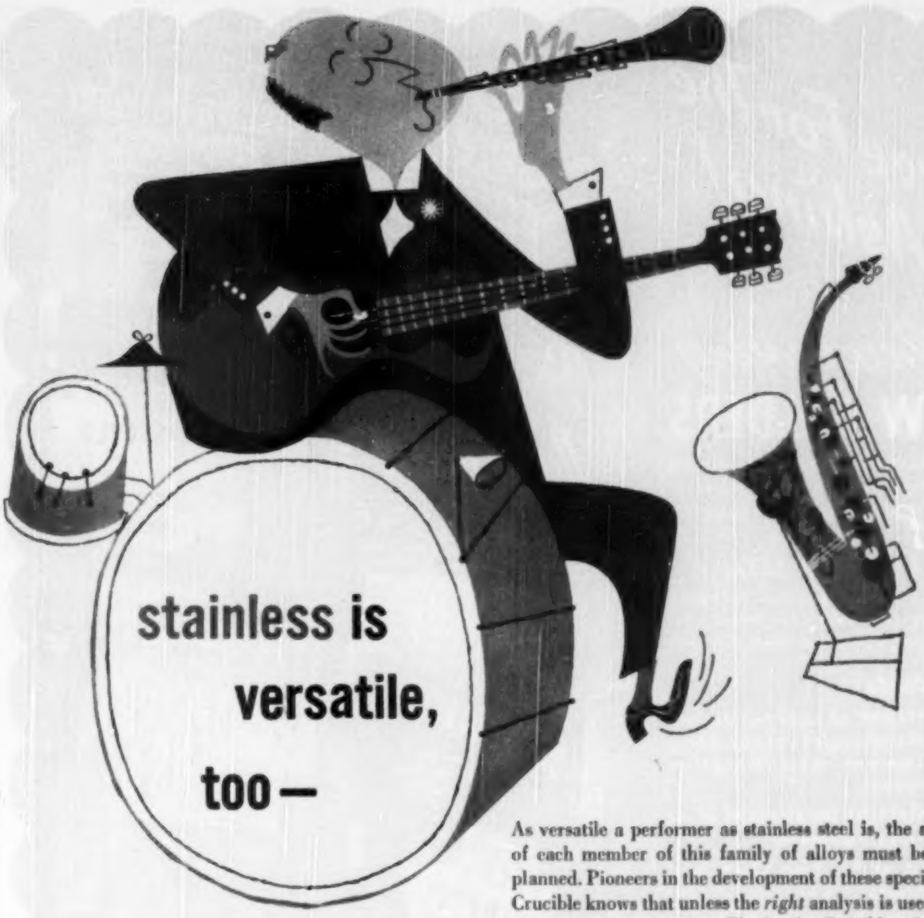

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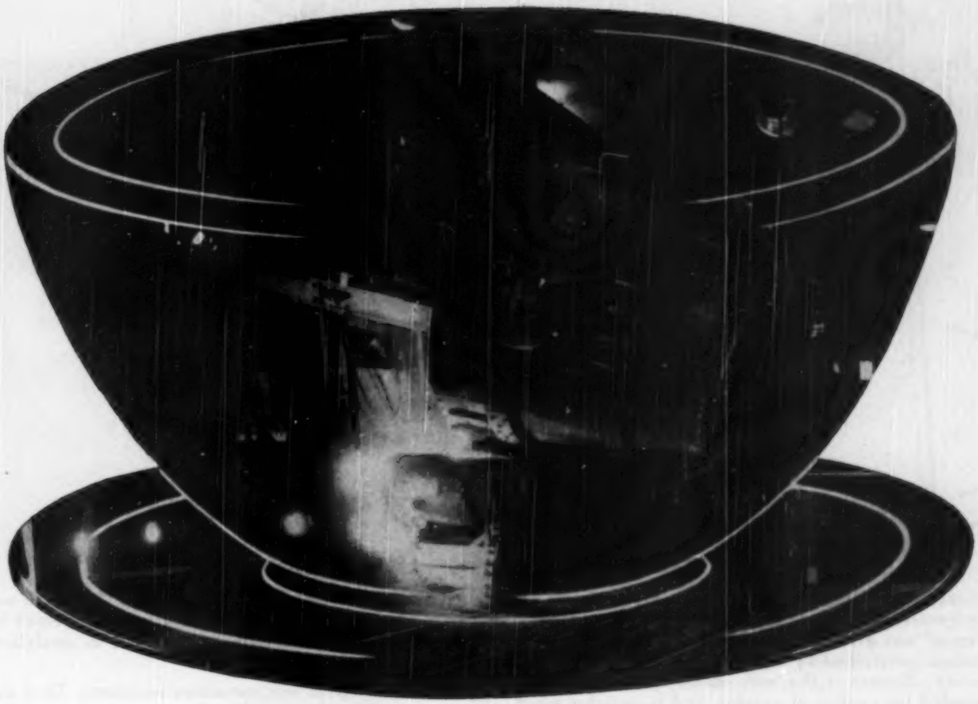

PERMAS*... the metal made especially for FISHER PERMAS WEIGHTS

No commonly available material matches perfectly all the specifications for analytical balance weights. Permas* was developed especially to conform to specifications prescribed by the Fisher Development Laboratory. Permas is the only metal specifically compounded for analytical weights, and it contains more than 50% non ferrous material.

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Permas Weights are harder. The surface resists abrasive action better than brass, bronze, gold, platinum, or any plating used on analytical weights.

Permas Weights are non-magnetic. They will not attract metallic particles and they are not affected by the damping magnets frequently used in analytical balances.

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Permas Weights are machined, by tungsten carbide tools, from rolled bar stock and polished to a permanent, durable, mirror-like finish.

*Permas—*permanent mass*—is a coined word, registered in the U. S. Patent Office, and is pronounced per'-mass.

Write for full information on all Fisher Permas Balance Weights.

The 100-gram set of Fisher Permas Weights illustrated at right is adjusted to tolerances required by the National Bureau of Standards for class "S" analytical weights. Price $52.00

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Isn't this a pretty kettle of fish?

SURVEYS reveal an appalling misunderstanding among young people of the "facts of business life." For example, a poll was made among seniors in certain high schools which showed that they believe business profits are "over 50%" of the sales dollar, where actually profits average less than 8%. These students also think that stockholders receive 24% of the sales dollar, where actually it runs less than 3%.

Isn't this a pretty kettle of fish?

A greater part of the 8% of the sales dollar is reinvested in the business to expand and improve plant facilities which protects employment and creates new jobs for more workers.

Such ignorance is alarming. It is unfair to the young people themselves and dangerous to America's furture. Such misconceptions open the door to socialism, communism and all the fantasies of the handout or "something-for-nothing" state of the economic dreamers.

Our school teachers say they *want* authentic information on the business system and how it works. Only business itself can supply the facts. You as a business leader in your commuuity must share the responsibility for this misunderstanding. It is our civic duty to help overcome this misconception of everyday economics in the minds of our youth today.

THE YOUNGSTOWN SHEET & TUBE CO. 1900 YOUNGSTOWN 1950 50 YEARS OF SERVICE

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General Offices--Youngstown 1, Ohio
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MANUFACTURERS OF CARBON ALLOY AND YOLOY STEELS

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Bulletin on
SUPER REFRACTORIES
by CARBORUNDUM
TRADE MARK

NO. 8 JUNE, 1950

Are Super Refractories Limited to High Temperature Applications?

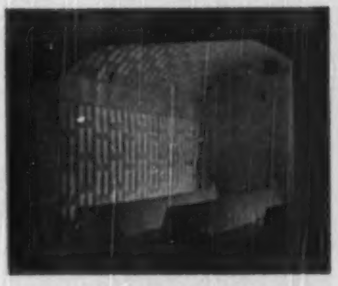
High temperature resistance is an inherent characteristic of super refractories by CARBORUNDUM. However, there are other properties which may be equally important reasons for selecting such refractories — for low as well as high temperature work.

The heat flow rate of CARBOFRAX silicon carbide refractories, for example, is practically the same (for the same temperature difference) at low temperatures as it is at high. Likewise, such properties as chemical stability, hot strength, wear resistance, and heat shock resistance are equally effective in low temperature jobs. Consequently, refractoriness as such, often becomes a secondary reason for picking a super refractory, even where elevated temperatures are involved.

Lowered fuel costs, more production, and appreciably reduced maintenance expenses are all demonstrated benefits of these super refractories that have been realized for reasons aside from high temperature resistance. And although other refractories may be considered adequate from a life standpoint in many low temperature jobs, there is every probability that substantial savings can be effected by proper use of *super refractories* by CARBORUNDUM.

Physical Properties of Super Refractories by CARBORUNDUM
Trade Mark

	CARBOFRAX Silicon Carbide	MULLFRAX Electric Furnace Mullite	MULLFRAX S Converted Kyanite	ALFRAX K Electrically Fused Alumina	ALFRAX B	ALFRAX BI
Heat Conductivity at 2200° F. in BTU/hr. sq. ft. and °F./in. of thickness	109 BTU	16 BTU	9 BTU	24 BTU	12 BTU	7 BTU
REFRACTORINESS PCE CONE	37-40	38-39	37-38	37-39	39-40	38-39
SPALLING RESISTANCE	High	High	High	Good	Good	Good
ABRASION RESISTANCE	High	Medium	Medium	High	Medium	Low
THERMAL EXPANSION (25° — 1400° C.)	.0000044	.0000059	.0000069	.0000074	.0000086	.0000086
MODULUS OF RUPTURE @ 2400° F. PSI	800-3125	100-250	175-475	100-1050	100-225	50-100
WEIGHT 9 IN. STRAIGHT	9.25 lbs.	9 lbs.	8 lbs.	10.1 lbs.	7.25 lbs.	4.8 lbs.



Muffle Performance Tells the Story

This photograph shows an ALFRAX electrically fused aluminum oxide muffle after six years in a porcelain enameling furnace. For four years, the furnace operated continuously on sheet steel and cast iron stove part production. Then, it was turned to stress-relieving work on heavy armor parts at a temperature of 1295° F. Loads of armor averaged 450 lbs. — were left in the furnace four hours. There were three loads a day, and during each change the temperature was dropped to 800° F. and then returned to its operating temperature.

After six years of this rigorous but relatively low temperature service, the only thing needed in this furnace was a new bottom! The low thermal expansion, chemical inertness and high cracking resistance of the ALFRAX tile kept the side walls and arch in first class condition — and without maintenance. Furthermore, high strength permitted use of thinner tile — aiding heat transfer through the muffle — and assisting fuel economy. Similar advantages are possible in other installations, involving either high or low temperatures.

Uniform Heat Flow Required Here

Used over a varnish fire, this dome provides a soft, even radiant heat. This results from the high thermal conductivity of the CARBOFRAX silicon carbide material. Its use facilitates the "cooking" operation — extends kettle life. Resisting repeated heating and cooling, the CARBOFRAX dome gives longer service and reduces repair bills.

Address all correspondence to: Dept. C-60, THE CARBORUNDUM COMPANY, Refractories Division, Perth Amboy, New Jersey

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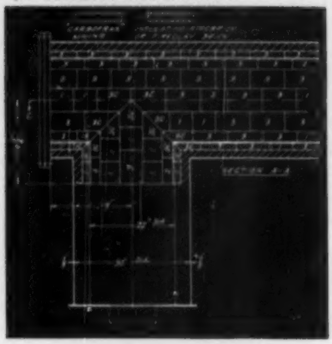
← Continued from other side

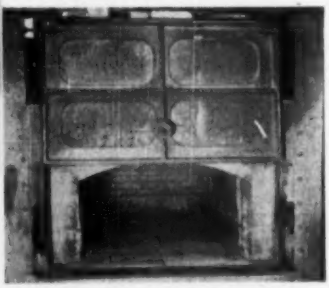


Hot Spots Eliminated in Flue Connector Linings

In the flue connecting a water-gas generator with its carburetor temperatures are relatively low. However, fireclay linings often erode in limited areas because of scurfing by the coke particles. Hot spots develop and production must be interrupted for repairs.

Since they are exceptionally resistant to erosion at both high and low temperatures, CARBOFRAX silicon carbide tile are ideally suited for this application. They retain their original thickness much longer, even at tees, ells and sweeps, where punishment is most severe. Also, the hard, dense CARBOFRAX tile resist carbon penetration and build-up. Elimination of expensive shutdowns, and of repeated repairs, quickly pays back the initial investment.

This is another example of where other specialized properties of CARBOFRAX brick and tile are more important than refractoriness.

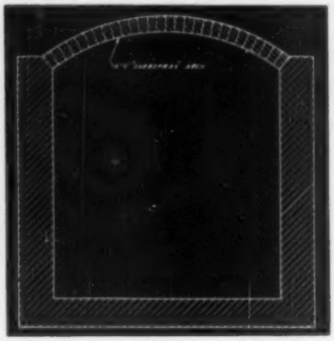


Abrasion, the Main Problem Here

Abrasion used to be the principal problem of this furnace. Operated at temperatures under 2000° F., the floor was worn away when aluminum-bronze castings weighing up to 700 lbs were dragged across it. The resultant unevenness of the hearth caused the castings to sag during heat treatment.

The problem has now been eliminated by using CARBOFRAX silicon carbide tile with their high abrasion resistance. The floor remains level, and distortion of castings avoided. Furthermore the hearth is still in operation after more than three years — a life figure that compares with about one a year for other types of hearths.

The high thermal conductivity of CARBOFRAX tile — another property equally useful at low temperatures — has also resulted in other improvements. First, more uniform and rapid heat delivery to the work chamber gives an improved heat treatment. Secondly, fuel consumption has been reduced. And, finally, the furnace can now be operated faster due to a quicker temperature come-back after being charged.



Super Refractory Picked for High Thermal Conductivity

This sulphur burner combustion chamber — shown in cross-section — is an interesting application of a CARBORUNDUM super refractory for a relatively low temperature job. The high thermal conductivity of CARBOFRAX silicon carbide brick is used to excellent advantage in the arch. Principally because of this feature it is possible to operate the unit at exceptional ratings and still maintain required temperatures of gases entering the Glover tower.

When a standard 9" thick fireclay arch is used in a burner of this type, approximately 1000 BTU's per hr. and sq. ft. are dissipated. A CARBOFRAX arch, however, dissipates approximately 4000 BTU's per hr. and sq. ft. This is due to the high thermal conductivity of the CARBOFRAX brick, and also because of the fact that their great mechanical strength makes possible an arch only 4½" thick. As a result, an extra ton of sulphur is burned each 24 hrs. per 24 sq. ft. of CARBOFRAX arch. Moreover, because of their low thermal expansion, inertness to furnace gases and absence of spalling and cracking, CARBOFRAX arches like this one are still in use after 18 years of continuous service.

Here Again, Refractoriness of Secondary Importance

In this gas-fired artware kiln, the high thermal conductivity of the CARBOFRAX silicon carbide muffle comes into play. It permits more rapid and uniform heat delivery to the ceramic ware -- with a consequent improvement in ware quality and a decrease in the number of rejected pieces. Moreover, it is unnecessary to maintain as high a temperature in the combustion chamber to secure the requisite heat in the working chamber — which means longer life for the other refractories — and lower fuel costs.

Other characteristics of CARBOFRAX tile important here are: High strength, which permits using thinner tile to further aid heat transfer; and high resistance to spalling and cracking which means long life in spite of repeated heating and cooling.

To obtain facts and figures on installations in specific fields merely select from this list of bulletins. Copies will be sent you at once. No obligation, of course.

- Super Refractories by CARBORUNDUM (general catalog)
- Super Refractories for the Ceramic Industry
- Super Refractories for the Process Industry
- Super Refractories for Boiler Furnaces
- Super Refractories for Heat Treatment Furnaces
- Super Refractories for Gas Generators
- The Frax Line of Cements
- CARBOFRAX Refractory Skid Rails
- Porous Media for Filtration & Diffusion

Dept. No. C-60

THE CARBORUNDUM COMPANY
Refractories Division
PERTH AMBOY, NEW JERSEY

SAVE SAVE SAVE

Famous Pangborn ROTOBLAST Tables (as shown here) assure high-quality cleaning of many kinds of castings, forgings and heat treated parts, at rock bottom cost.

on BLAST CLEANING with PANGBORN ROTOBLAST*

BY THE WEEK: One foundry, with ROTOBLAST, slashes *$211.56* every week off their blast cleaning bill. An additional saving in this case is *lower breakage losses*—important in any foundry producing intricate and fragile castings.

BY THE MONTH: One more foundry credits ROTOBLAST with saving $423.30 *each month* on blast cleaning. To prove that blast cleaning goes faster with ROTOBLAST, castings are now cleaned in 1/3 the time it used to take!

BY THE YEAR: $10,160 saved on labor alone each year—that's the story from a large ROTOBLAST-equipped foundry. But there are still more savings: five old-fashioned machines with bothersome dust have been completely eliminated—important for a foundry where space is at a premium!

ROTOBLAST makes cash savings possible these five different ways:

SAVES LABOR: One ROTOBLAST machine and operator can do as much as a two-man crew and old-fashioned equipment.

SAVES SPACE: In many cases, one ROTOBLAST machine replaces five or more old-fashioned machines, requires less space.

SAVES TIME: Cases on record prove ROTOBLAST can cut cleaning time up to 95.8% compared to older methods.

SAVES POWER: Modern ROTOBLAST uses but 15-20 h.p. compared to old-fashioned equipment requiring 120 h.p. for same job.

SAVES TOOLS: On work cleaned with ROTOBLAST, cutting tools last up to 3 times longer because no scale is left to dull edges.

SAVINGS mean PROFITS

Find out how much you can save! If you're hampered by old-fashioned blast cleaning methods, you can *save money* with ROTOBLAST. There's a modern, economical, efficient ROTOBLAST *Barrel, Room, Table* or *Table-Room* especially designed to solve every blast cleaning problem. Let Pangborn engineers show what ROTOBLAST can do for you. Write today for Bulletin 214 to PANGBORN CORPORATION, 1404 Pangborn Blvd., Hagerstown, Maryland.

Look to Pangborn for the Latest Developments in Blast Cleaning and Dust Control Equipment

MORE THAN 25,000 PANGBORN MACHINES SERVING INDUSTRY

Pangborn FEMA

*Trademark of Pangborn Corporation

BLAST CLEANS CHEAPER with the right equipment for every job

This tubular fireman always rings the bell!

courtesy

Beacon Devices, Inc.

Here's a fire warning that never fails—a bottle of compressed CO_2 that keeps watch while you're asleep. The moment temperature reaches 130° F, gas is automatically released into the whistle stem . . . result, a warning blast audible for a quarter mile.

Both cylinder and whistle for this self-contained signal are fabricated from seamless mechanical tube—right out of Frasse warehouse stocks. The manufacturer makes it a policy to rely on Frasse tubing for his fire warning and fire fighting devices. For, along with 24 hour delivery convenience, he has found dependability . . . every cylinder withstands a pressure test of 3,000 psi—in 8 years *he has never had a failure.*

Whatever your quality tubing requirements, make it a point to check the wide variety of specifications and sizes available immediately from Frasse warehouses. You'll find mechanical tubing, stainless tubing, aircraft tubes, and condenser, hydraulic and pressure tubes in unusually complete selections. And Frasse engineering facilities ready to help you choose for most economical advantage. *Call Peter A. Frasse and Co., Inc., 17 Grand Street, New York 13, N. Y. (Walker 5-2200) • 3911 Wissahickon Ave., Philadelphia 29, Pa. (Baldwin 9-9900) • 50 Exchange Street, Buffalo 3, N. Y. (Washington 2000) • Jersey City • Syracuse • Hartford • Rochester Baltimore*

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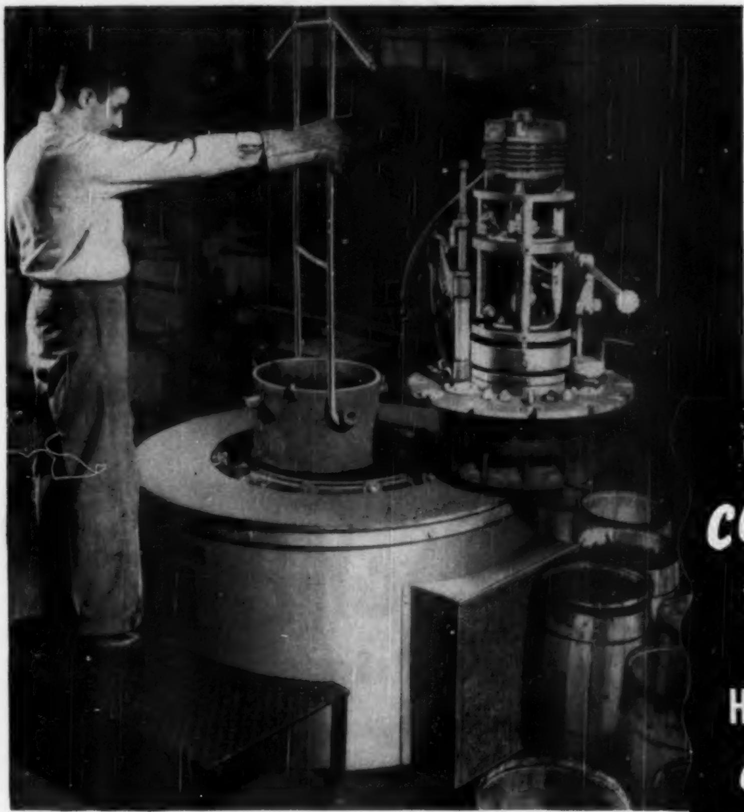

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Here's a temperature instrument especially suited to metal plants. Practically eliminates instrument maintenance because it has no slidewire, requires no standardizing, uses no dry cell. Yet it is unmatched in sensitivity, accuracy, and speed of response. Write for Bulletin 427-1. **The Foxboro Company, 52 Neponset Ave., Foxboro, Mass., U. S. A.**

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ELECTROMET Data Sheet

A Digest of the Production, Properties, and Uses of Steels and Other Metals

Published by Electro Metallurgical Division, Union Carbide and Carbon Corporation, 30 East 42nd Street, New York 17, N. Y. • In Canada: Electro Metallurgical Company of Canada, Limited, Welland, Ontario

How to Control Composition of Cast Iron With Silicon and Manganese Briquets

Control of the composition of cupola-melted cast iron becomes a simple matter through the use of alloy briquets.

These briquets make the old practice of blending two or three pig irons of high and low silicon and manganese contents, to produce a desired composition, both unnecessary and undesirable. A single grade of pig iron can be stocked, and any desired composition in the product can be obtained, simply and economically, by the addition of silicon and manganese briquets.

Function of Silicon in Iron

In cast iron, silicon acts as a deoxidizer and graphitizer. It promotes the formation of flake graphite and softens the iron.

When either the carbon or silicon content of an iron is too low for the section thickness involved, the result will be the formation of chilled spots (iron carbide) at corners and in other rapidly cooled locations. This has an adverse effect on the machinability of the iron and the life of the tools used to machine it. On the other hand, excessively high carbon or silicon content in heavier sections results in open-grained iron that is both soft and weak.

How Silicon Aids Carbon Control

A rather definite relationship exists between the silicon level in a pig iron and its carbon content, as shown in Figure 1.

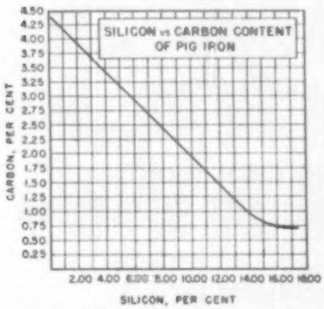

Fig. 1—Relation of silicon and carbon content in pig iron. Notice that the carbon level gradually decreases as the silicon is increased.

As indicated in this chart, an increase in the silicon content of a pig iron has a decided effect in lowering its carbon content. When producing soft iron, where it is desirable to hold the carbon on the high side, pig iron running in the range of 2.0 per cent silicon is desirable in the cupola charge, rather than the higher silicon grades of pig sometimes used in these irons. The additional silicon needed to meet the desired chemical analysis can be easily and economically added to the charge in the form of silicon briquets. This provides an economical and flexible system of chemical control.

Function of Manganese in Iron

Manganese acts as a scavenger to deoxidize iron. As an alloying element, it imparts density and high strength. It combines with sulphur to form manganese sulphide, which does not have the harmful characteristics of the iron-sulphide inclusions that form when manganese is not present. A manganese-sulphur ratio of 6:1 is suggested.

Briquets Give High Alloy Recovery

Silicon and manganese briquets are available from ELECTROMET in the sizes shown in Table I. These "EM" briquets are all made with a binder that prevents oxidation until the alloy unites with the iron in the melting zone of the cupola. Thus, the recovery of alloy is high—usually over 90 per cent for silicon and about 85 per cent for manganese.

More Scrap, Less Pig in Charge

Foundries can use an increased amount of scrap in the charge because the analysis of the iron can be adjusted by adding "EM" briquets. This reduces material costs and makes possible substantial savings in cupola operation.

Booklet Available

Further information is given in our booklet, "Briquetted Alloys For The Iron Foundry Industry." To obtain a copy, free of charge, write or phone our nearest office: in Birmingham, Chicago, Cleveland, Detroit, Los Angeles, New York, Pittsburgh, or San Francisco.

Table I. "EM" Briquetted Alloys for Cupola Additions

Type of Briquet	*Gross Weight*	*Alloy Content*
"EM" Silicon Briquets (two sizes) Round	5 lb.	2 lb. Silicon
	2½ lb.	1 lb. Silicon
"EM" Silicomanganese Briquets Square	3½ lb.	½ lb. Silicon 2 lb. Manganese
"EM" Ferromanganese Briquets Oblong	3 lb.	2 lb. Manganese

Table II. Typical Briquet Mixture for Soft Gray Iron

Base Charge		Material Charged	Alloys in Charge Material			
			Silicon		Manganese	
Per Cent	*Lb.*		*Per Cent*	*Lb.*	*Per Cent*	*Lb.*
40.0	400	Pig Iron	2.25	9.00	0.75	3.00
40.0	400	Return Scrap	2.50	10.00	0.65	2.60
20.0	200	Purchased Scrap	2.28	4.56	0.55	1.10
100.0%	1,000 lb.	Total Base Charge		23.56		6.70
Briquets Required		4 Small Silicon Briquets		4.00		—
		½ Silicomanganese Briquet		0.25		1.00
		Total Alloys Charged		27.81 lb. Si or 2.78% Si		7.70 lb. Mn or 0.77% Mn
		Melting Recovery Factor		x .90		x .85
		Final Analysis of Iron		2.50% Si		0.65% Mn

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The striking qualities of the Misco Precision Casting Process, described in our booklet, are of particular interest to engineers, metallurgists, production and purchasing executives. If your requirements call for quantity production of small complex parts in high strength, wear resistant, and heat and corrosion resistant steel alloys you need this booklet.

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ENGINEERING DIGEST OF NEW PRODUCTS

X-RAY "MAXISERVICE" PLAN: A revolutionary service plan that will enable industry to cut costs, perform research and control product quality without investing in equipment has been announced by General Electric X-Ray Corp.

For the first time in the history of the X-ray manufacturing business, according to John H. Smith, president of the firm, industry will be offered not merely an X-ray apparatus, but a "packaged" X-ray service, complete with equipment, maintenance, repair parts, tubes and instruction—all covered by one monthly charge.

In the few years that X-ray has been tested and applied by industry, it has grown at an ever-increasing rate in three different directions. Food processors and manufacturers of sundry assemblies have found that X-ray fluoroscopy controls and improves the quality of their products by detecting hidden faults. Metal fabricators and foundries with X-ray inspection have improved process control and sales acceptance in many forms of fusion welding; foundries have developed casting techniques with X-ray that result in lower production costs, increased yield and reduced scrap. Research and process control laboratories use X-ray diffraction for qualitative and quantitative analysis of chemical compounds and metallurgical processes to develop new products and control quality of existing processes.

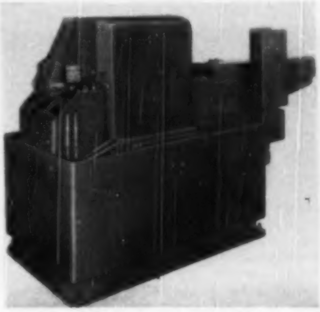
Under "Maxiservice" the one monthly charge covers everything in one package — rental of the equipment, instruction in its use, maintenance service, replacement parts, tubes, property taxes and interest costs, all without investment. This will place X-ray within the reach of a vastly greater number of industrial firms and laboratories.

The monthly payment is 100% chargeable against operating expenses. It eliminates the problem of depreciation entirely. It puts upon the General Electric X-Ray Corp. the responsibility for keeping the apparatus always in top operating condition. It eliminates the obsolescence risks, since new equipment is available with no investment. It provides fixed, easy-to-budget costs. It makes it easy to change or add to equipment, as needed; and it helps the user earn as he goes.

For further information circle No. 429 on literature request card on p. 732A

AUTOMATIC FORMING MACHINE: Forming operations of external grooves and shapes as well as various end operations can be performed on tubular or solid stock by the new Motch & Merryweather Automatic Forming Machine.

Single or double, hollow, collet-type spindles are available and banks of double spindle machines could be formed as production requirements dictate. The heavy duty tool slides carry the form and end operation tools, advancing and retracting automatically by positive cam operation. When arranged as an automatic bar feed machine, a magazine stock loader can be provided. Hopper loading from the front or rear can also be furnished to meet specific needs. The entire cycle of this double spindle machine is actuated mechanically by a single cam shaft. The geared drive of the cam shaft contained in the base has pick-off gears so that the cycle time can be easily changed to reach ultimate production with good tool life. The spindles are driven by individual V-belt motor drives housed in a separate compartment in the machine base. The welded steel base also contains the coolant sump and large chip compartment with access doors for easy chip removal.



For further information circle No. 430 on literature request card on p. 732A

COLD DRAWN SEAMLESS TUBING OF ROSSLYN METAL: Cold drawn seamless tubing of Rosslyn Metal, copper core with stainless steel surfaces, has been successfully accomplished by American Cladmetals Company. Of wide application in freezing and heating units, the Rosslyn Metal seamless tubing will result in material savings in that wide field. It will have particular application in the dairy industry.

Due to the copper in Rosslyn, swift heat and cold transfer is possible, while the stainless steel surfaces, to which the copper is bonded permanently, provide hardness, resistance to corrosion and ease of cleaning. Since most heat exchangers are tubular in construction, this new accomplishment will mean fuel economies because of the faster heat transfer rate of Rosslyn as compared to metals now commonly used.

A saving in vital space will be made, for less of this new seamless tubing is necessary than if solid conventional tubing is employed. This is vital in freezing units such as refrigerators and in heating units as tubular boilers.

The first seamless tubing made of Rosslyn consisted of a section 1⅛ in. o.d. by 0.50 wall. Successful drawings in other sizes have since been made. The size range is expected to be from ⅝ to 1⅛ in. o.d. and from 0.020 to 0.078 in. wall thickness. The maximum weight for a piece of tubing at the present time is about 5 lbs.

Rosslyn Metal seamless tubing is made by a unique method — by first drawing a tube hollow or tube billet from a flat sheet. Successive draws and anneals were employed until a tube hollow 2⅝ in. o.d. by 18 in. long and approximately ⅛ in. thick was produced. This tube hollow was then redrawn by conventional methods to thin wall seamless tubing.

For further information circle No. 431 on literature request card on p. 732A

VACUUM PUMP: A new compound vacuum pump, Model CVD 3534, has been developed by Kinney Mfg. Co.

Model CVD 3534 has a free air displacement of 4.9 cu. ft. per min. (139 liters per min.) and operates with a ⅓ hp. motor. On a blank test, each unit is required to produce McLeod gage absolute pressure readings of 0.1 micron (0.001 mm. Hg) or better. This model is extremely compact — less than 16 in. high. It is ruggedly built, quiet in operation, and easy to service. Double sealing-oil reservoirs provide continuous oil purification which promotes the consistent production of high vacuum regardless of surrounding atmospheric conditions. The new pump requires no "warm-up" period.

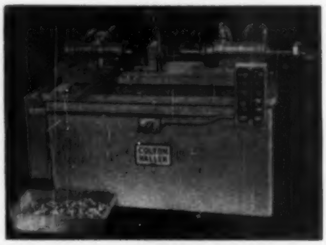
For further information circle No. 432 on literature request card on p. 732A

NEW PRODUCTS

POWDERED METAL PRESS: The Arthur Colton Div. of Snyder Tool & Engineering Co. will build and market powdered metal presses incorporating the patents, designs and process techniques developed by Michigan Powdered Metal Products Co.

The accomplishments of John Haller, president of Michigan Powdered Metal Products Co., have achieved wide recognition in the field of powdered metal techniques, particularly as these techniques apply to the production of complex parts, such as his "oil-well" bearings.

The new Colton-Haller presses will be made in the following capacities: 25 ton with 5 in. fill, 40 ton with 8 in. fill, 100 ton with 9 in. fill, and 125 ton with 9 in. fill. The 25 ton is a two tie-rod press; the others are four tie-rod presses. Fills are adjustable from zero to the machine's capacity, and filling is by means of a reciprocating shoe mechanism for powdered metal work. A shuttle feed is available for plastic pre-form work.



All machines are designed for rapid approach speeds, and slow pressing speeds. All offer the recognized advantages of hydraulic operation at high pressures in processing powdered brasses, copper alloys, iron, steel, stainless steel, aluminum, etc.

A wide variety of motions are available in these presses: one from above and one from below with stationary core-rod; one above, two below, both pressing motions; one above, two below, one of the latter a pressing motion and the internal motion a movable core-rod; two above and one below; two above and two below. As a special optional feature, these presses can be built to include a floating die table.

A unique item in the Colton-Haller line will be a new horizontal hydraulically operated sizing press with a number of patented features — the first press of its kind to be built in the United States.

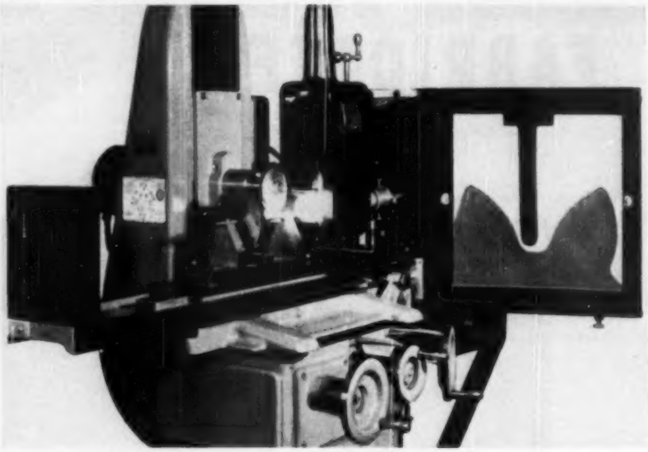
For further information circle No. 433 on literature request card on p. 732A

"VISUAL-GRIND" CONTOUR GRINDING MACHINE: A "Visual-Grind" Contour Grinding Machine has been developed by the Cleveland Grinding Machine Co. For the first time, three techniques in optical contour grinding are available in the same machine — image, profile and templet. Each technique excels for specific purposes. Many involved set-ups are avoided which would be necessary in ordinary machines. Also, inspection is continuous as grinding progresses, there being no occasion for referring frequently to a comparator.

The company's so-called "bounce-back" feature makes possible "reflecto-image" grinding. The light, descending from its source in the lamp house, is condensed onto an oblique reflector which directs the beam to the left against the front of the workpiece. The image is reflected horizontally to the right through an aperture in the reflector, passes through precision lenses for magnification, and is projected on the screen without inversion or reversal.

Profile projection is performed by placing an auxiliary mirror behind the workpiece. The light which carries past the work and the grinding wheel is reflected back through the aperture and through the lenses to the ground-glass screen. A profile of the workpiece shows as a sharp, dark image on the brightly illuminated screen without indistinct edges. The profile method is ideal for all jobs in which front and rear surfaces of the workpiece are alike in size and shape.

The templet technique combines reflecto-image and profile projection. A polished precision templet of in-



tended shape is fastened to the front of the workpiece. "Photographs" of both templet and workpiece are projected on the screen simultaneously. The workpiece can then be accurately ground to the desired form by matching its greatly magnified image with that of the templet. Templet grinding opens new possibilities in that the templet readily guides stock removal when wide contours at high magnifications are too large to be drawn on the screen. No drawing need be scribed on the screen.
For further information circle No. 434 on literature request card on p. 732A

MACHINE FOR ARGON METAL ARC WELDING OF ALUMINUM: A new machine for automatic welding of aluminum by the argon-shielded metal-arc welding process has been announced by the Linde Air Products Co., unit of Union Carbide and Carbon Corp. This welding machine uses an arc maintained in a shield of argon gas between the consumable filler-metal electrode and the workpiece. The electrode, supplied as a coil of wire, is deposited across the arc into the weld as filler metal. The process is applicable to either machine or hand welding, and can be used for all of the metals that are readily

(Continued on p. 731)

NEW PRODUCTS

(Continued from p. 730)

joined by heliarc welding. The initial effort is being concentrated on the welding of aluminum plate. The equipment for mechanized welding is known as the "Linde" FSM-1 machine.

Welds are clean and smooth. No flux is used. The possibility of flux corrosion or entrapment is eliminated, and cost of cleaning and finishing the welds is sharply reduced. Welding is fast and weld quality high. The aluminum alloys, welded commercially by this process, presently include 2S, 3S, 52-S and 61-S in plates ¼ to 1⅛ in. thick. Almost any thickness can be welded by a suitable number of passes. With the FSM-1 machine now available, butt welding is performed in the flat position, and fillet and lap welding in the flat and horizontal positions.

For further information circle No. 435 on literature request card on p. 732A

WELDING ELECTRODES FOR HIGH TENSILE STEELS: Arcos Corp. announces the development of three new additions to their line of low hydrogen welding electrodes. Known as the Tensilend electrodes, they simplify fabrication by the elimination of preheat in welding low-alloy high-strength steels in the 70,000, 100,000 and 120,000 psi. tensile strength class.

The electrode called Tensilend 70, developed for welding steels in the 70,000 psi. class, is believed to have the broadest field of application. With its stainless-type coating and high-tensile weld deposit, it can be used for welding low-alloy high-strength steels and also for welding mild steels under highly restrained conditions, high-carbon steels, and sulphur-bearing free-machining steels. Tensilend 120, for 120,000 psi. steels, was developed for marine applications, such as welding armor plate, and its further possibilities are still being explored.

Because these electrodes will perform satisfactorily without preheat, even in freezing temperatures, they are expected to lower the costs of metal fabrication and to be especially useful in field work.

These low hydrogen electrodes leave a mild steel deposit, but differ from most mild steel electrodes in possessing higher tensile strength, better elongation and better impact strength at both room and freezing temperatures.

(Continued on p. 732)

ENGINEERING DIGEST OF NEW PRODUCTS

(Continued from p. 731)

By eliminating preheat, they overcome a fabrication problem of cast steel foundries, and without annealing, provide sound, crack-free welds with properties comparable to those of the cast steel after the customary stress relieving heat treatment. Since there is no underbead cracking, sound welds in less time can also be produced by builders of rolling stock, such as railroad cars, trucks, construction and earth moving equipment, who are welding the newer high-strength alloy steels to eliminate dead weight. **For further information circle No. 436 on literature request card on p. 732A**

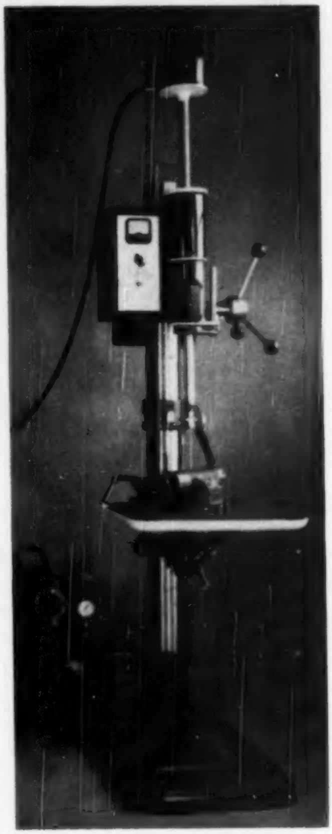
ELECTRON DRILL: A new Electron Drill, developed and manufactured by the Elox Corp. now approaches or equals the speed of twist drilling, according to the company.

This motor-driven automatic hard metal drilling machine employs an entirely new patented electronic principle of operation and while using only 1/5th of the usual power, increases the speed of cutting hardened steels as much as 15 times above previous Elox models.

The Electron Drill has a myriad of applications and was originally designed for production cutting of extremely small as well as large holes in hardened metals and for production removal of taps, drills and reamers in a wide variety of sizes.

The Electron Drill is entirely automatic. It also can be hand fed by the operation of a simple switch and will chuck up 36 in. of electrode. It is extremely reliable and sensitive, giving perfect control as well as fast speeds on standard electrodes from 0.040 to 0.750 in. and larger. Simple to operate, the Electron Drill requires no more knowledge to operate than a drill press, and cannot be damaged by operator abuse.

Designed as a production machine for drilling out broken tools or drilling holes in hardened metals, the Electron Drill will not affect or damage the material being worked on, i.e., annealing or hardening the workpiece. There is no sticking or welding; and no resetting of the machine



is required during the drilling operation. Electron Drill holes can be reamed to exact size without grinding or other preparation.

The Elox Electron Drill has a nominal 2 kva. rating, using current at approximately the same rate as an electric toaster. It will operate from any 110-v. 60-cycle lighting system, eliminating the necessity of any special power supply.

Using the ⅛ in. optimum size electrode, typical time cycles for drilling are: 25 sec. for ¼ in. hole; 60 sec. for ½ in. hole; 140 sec. for 1 in. hole.

According to the company, the Electron Drill will drill carboloy, nickel and cobalt steels, nickel and chrome steels, manganese steels, stellite, cast iron, copper and copper alloys, aluminum, Alnico, lead, zinc and many others.
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(Continued from p. 731)

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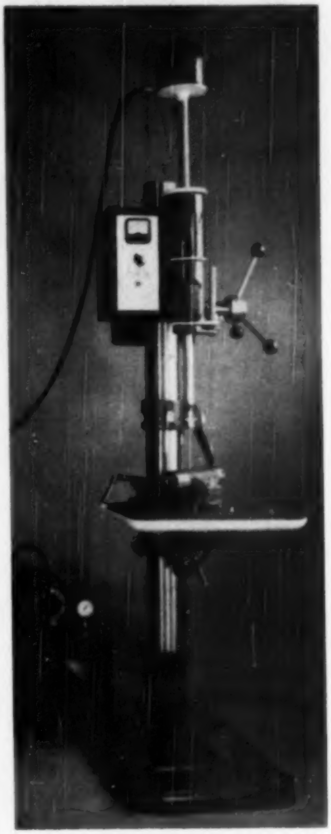

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For further information circle No. 437 on literature request card on p. 732A

438. Air-Gas Mixer
Bulletin L-600 describes the new McKee Consta-Mix proportioning valve for complete accuracy in a wide range of operations for industrial gas users. *Eclipse Fuel Engineering Co.*

439. Alloy Tubing
New catalog contains complete list of products and prices in warehouse stock of alloy steel tubing. *Timken Roller Bearing Co.*

440. Alloys, Bronze
New Ampco Metal Catalog gives complete information on physical properties of various grades of Ampco aluminum bronze alloys. *Ampco Metal, Inc.*

441. Alloys, Fabricated
New catalog is available, showing cost-cutting fabricated heat treating equipment for higher pay loads and better quality. *Rolock, Inc.*

442. Alloys, Nickel
New technical bulletin T-6 discusses resistance of nickel and its alloys to corrosion by caustic alkalies. *International Nickel Co.*

443. Alloys, Nickel
Hastelloy nickel-base alloys are available for fabricating corrosion-resistant screen, cloth and baskets. Also for metal spraying many types of automatic welding and hard-facing. Booklet, "Hastelloy High-Strength Nickel-Base Corrosion-Resistant Alloys", gives full details. *Haynes Stellite Co*

444. Alloys, Nickel
Technical bulletin, "Cast 16% Cr – 35% Ni Alloys", completely illustrates heat, corrosion and abrasive-resistant cast alloys. *Electro Alloys Div.*

445. Aluminum
Copy of "Alcoa Aluminum Impact Extrusions" will be sent on letterhead request, giving full information on impact extrusion process and service. Shows whole range of shapes for engineering. *Aluminum Co. of America.*

446. Ammonia
Booklet, "Mathieson Anhydrous Ammonia", furnishes full information on obtaining purest ammonia from 40 conveniently located warehouses. *Mathieson Chemical Corp.*

447. Belts, Metal
Bulletin 47P illustrates and describes complete line of wire belts for industry. *Ashworth Brothers, Inc.*

448. Bimetal Elements
64-page catalog written especially to help the design and product engineer select the type and size of thermostatic bimetal element best suited to his temperature-responsive device. *W. M. Chace Co.*

449. Blast Cleaning
There is a Pangborn rotoblast table, barrel, or table-room designed to bring you amazing savings. Write for bulletin 214. *Pangborn Corp.*

450. Castings, Steel
New bulletin describes Pyrasteel, the chromium-nickel-silicon alloy with prime qualities for resisting oxidation and corrosion up to 2000°F and for withstanding most concentrated or dilute commercial acids and corrosive gases. *Chicago Steel Foundry Co.*

451. Cleaning Machine
Carbo-cleaner, the most compact, lowest priced carburizing-compound-cleaning machine on the market. Write for further details. *Thurner Engineering Co.*

452. Coatings, Metal
Explanations of high-vacuum evaporation of metals and other solids set forth in detail in new 12-page booklet, "Vaporized Metal-Coatings by High Vacuum". *Distillation Products, Inc.*

453. Combustion Chambers, Graphite
M-9602 describes the graphite combustion chambers and "Karbate" impervious graphite burner nozzles. Outlines operation of the complete system and points out the principal features, such as long life, absence of corrosion, minimum maintenance, ability to withstand thermal shock, simplicity and moderate installed first cost. *National Carbon Co.*

454. Control Devices
New 64-page catalog 8303 illustrates over 100 different industrial control devices for temperature, flow, pressure, liquid level and humidity. *Brown Instrument Co.*

455. Control Instruments
Booklet CAB-1 contains description of new "Cabinet Series" control panel with suggestions for combining auxiliary equipment. *Wheelco Instruments Co.*

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

456. Copper Alloys
28-page booklet entitled "Copper and Copper Alloys Specifications Index". Section 1 lists most generally used alloys together with all applicable specifications. Section 2 lists specifications in numerical order with brief description of materials covered. *American Brass Co.*

457. Copper Sheets
New 23-page booklet, the product of a ten-year program of design developments and tests combined with field investigations, contains complete, detailed specifications for all types of sheet metal installations employing copper. *Revere Copper & Brass, Inc.*

458. Cutting Oils
Write today for the pamphlet, "New Improved Gulf L.S. Cutting Base", which describes how production can be speeded up with lower costs and better finishes by using this newly developed cutting oil. *Gulf Oil Corp.*

459. Descaling
Booklet entitled "duPont Sodium Hydride Descaling Process" discusses the process, how it works and where it is used, along with interesting photographs, diagrams and technical information, designed to help you get the most out of your scale-removal jobs. *E. I. duPont de Nemours & Co., Inc.*

460. Electrodes, Welding
New catalog presents complete line of shielded-arc electrodes for welding of mild steels and alloy steels; gives complete specifications, operating characteristics, mechanical properties, and applications. *McKay Co.*

461. Electropolishing
New bulletin illustrates and discusses the electropolishing of stainless steel. This process eliminates mechanical polishing methods for many products or may be used in conjunction with them. *American Steel & Wire Co.*

462. Finishes
New "Black Book" gives full details on Black Magic finishes for steel, iron, zinc, cadmium, copper and its alloys. *Mitchell-Bradford Chemical Co.*

463. Finishing
Alodine aluminum bonds paint to aluminum and protects the metal economically, with no plating equipment required. Applied with dip, spray, brush and flow coat, it provides a simple, easy process for lasting, corrosion-resistant finish. *American Chemical Paint Co.*

464. Fittings, Stainless Steel
New stainless steel welding fittings price list (52W) contains latest prices covering a variety of fittings such as elbows, return bends, stub ends, tees, etc., in types 304, 316 and 347 stainless steel. *Cooper Alloy Foundry Co.*

465. Furnaces
New combustion system and furnace design provide fast, high-temperature heating for production forging. Fully described in bulletin SC-144. *Surface Combustion Corp.*

466. Furnaces
Bulletin T-1420 illustrates and describes Lindberg LI-25 induction heating unit. A ruggedly constructed vacuum-tube type of unit for hard working production-line jobs. Ideal for hardening, brazing and soldering, annealing and stress relieving, hot forming and light forging, shrink fitting and other induction heating applications. *Lindberg Engineering Co.*

467. Furnaces
New 32-page fully illustrated catalog on Vapocarb-Hump furnaces. Describes the triple-control method of regulating atmosphere, and features improved control by use of fluid pump assembly. *Leeds & Northrup Co.*

468. Furnaces
New all-purpose furnace described in bulletin HD-646 may be used for carburizing, nitriding, dry cyaniding, bright annealing and clean hardening. *Hevi Duty Electric Co.*

469. Furnaces
New bulletin on Malleable Iron Annealing Furnaces contains photographic description and sectional drawings of this furnace, and also describes the low-hydrogen gas generator for controlled-atmosphere malleable annealing. *Holcroft & Co.*

470. Furnaces
Catalog 110 features new heat treating furnaces and atmosphere charts. *C. I. Hayes, Inc.*

471. Furnaces
New catalog on Heroult gantry-type electric melting furnace with patented roof-ring to assure speedy and simple bricking and elimination of skew shapes. *American Bridge Co.*

472. Furnaces, Brazing
Fully descriptive folder on furnace brazing, with many suggested "do's" and "don'ts". *Electric Furnace Co.*

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FIRST CLASS
PERMIT No. 1595
(Sec. 34.9 P.L. & R.)
Cleveland, Ohio

BUSINESS REPLY CARD
No Postage Stamp Necessary If Mailed In the United States

4¢ POSTAGE WILL BE PAID BY—

METAL PROGRESS
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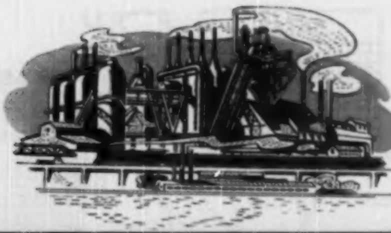
CLEVELAND 3, OHIO



"NATIONAL" Ground Anodes control underground corrosion positively!

Losses due to underground corrosion *on pipe lines alone* are estimated at $600,000,000 annually. Protect *your* buried or submerged metal structures, positively and economically, by installing "National" ground anodes.

Regardless of seasonal changes in soil resistance—regardless of whether the soil is wet or dry—"National" ground anodes afford perfect protection against corrosion. They operate with a controllable electric circuit. In dry periods, simply raise the voltage. In wet periods, lower it.

"National" ground anodes have been used for more than 15 years. They outlast any other material. You don't have to dig them up every few years. For highest efficiency, pack "National" graphite backfill material around each anode in the bed.

For complete details, write to Dept. MP.

MORE THAN DOUBLE THE USABLE LIGHT!

The biggest news since the invention of flashlights—the brand new "Eveready" No. 1050 flashlight battery—gives more than double the usable brilliant white light for critical uses than any other flashlight battery we have ever made.

NO METAL CAN TO LEAK OR CORRODE

The terms "National" and "Eveready" are registered trade-marks of

NATIONAL CARBON DIVISION
UNION CARBIDE AND CARBON CORPORATION
30 East 42nd Street, New York 17, N.Y.
District Sales Offices: Atlanta, Chicago, Dallas, Kansas City, New York, Pittsburgh, San Francisco
Foreign Department: New York, U.S.A.

These products sold in Canada by National Carbon Limited, Toronto 4

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

473. Grinding and Polishing
New booklet entitled "Why Thousands of Shops Have Switched" describes advantages of back-stand grinding and polishing metalite cloth belts. *Behr-Manning Corp.*

474. Grinding Wheel
Illustrated bulletin describes the Norton reinforced Hub Wheel for use on standard right-angle portable grinders and sanders. *Norton Co.*

475. Hardness Tester
Illustrated circular describing the Ames portable hardness tester in sizes for work 1" to 6" round and flat. *Ames Precision Machine Works.*

476. Hardness Testers
Bulletin DH-114 contains full information on Tukon hardness testers for use in research and industrial testing of metallic and nonmetallic materials. Also included is bulletin DH-7, giving experiences in various fields. *Wilson Mechanical Instrument Co.*

477. Heat Treating
Pressed steel lightweight sheet alloy heat treating units furnished in any size, design or specification. Write for full information on this. *The Pressed Steel Co.*

478. Heating Elements, Electric
Bulletin H gives detailed information on AT-type nonmetallic electric heating elements, including tables for a wide variety of sizes available. *Globar Div., Carborundum Co.*

479. High-Temperature Testing
For precise hi-temperature testing send for illustrated technical folder on Marshall equipment. *L. H. Marshall Co.*

480. Holders, Laboratory
24-page booklet, "Castaloy Laboratory Appliances", presents a complete line of holders, clamps, and supports for holding laboratory equipment and assemblies. *Fisher Scientific Co.*

481. Immersion Heating
Bulletin IE-11 gives complete details on how new immersion pots save time and money in melting soft metals. High thermal efficiency for both large and small units provides rapid heat recovery in one-third the time. *C. M. Kemp Mfg. Co.*

482. Induction Heating
More economical production made possible through redesign of heat treating methods. Full details on application to individual plants furnished in booklet, "A Tocco Plant Survey — Your Profit Possibility for 1950". *Ohio Crankshaft Co.*

483. Lithium
28-page booklet, "Lithium in Modern Industry", reviews and forecasts significant developments in Lithium chemistry since 1940. *Foote Mineral Co.*

484. Machine Design
Fundamentals of producing low-cost machine parts — design, material and treatment — are discussed in new 72-page "Three Keys to Satisfaction". *Climax Molybdenum Co.*

485. Metalworking Data File
Fingertip reference file 502 contains engineering information about equipment and processes used for metal stampings, heavy weldments and pressed steel shapes. *Chas. T. Brandt, Inc.*

486. Melting, Induction
8-page illustrated article describes use of induction melting in improved technique for rotor-casting. *Ajax Engineering Corp.*

487. Microscopes
Catalog D-1010 illustrates and describes new E series of microscopes for the most exacting research work. *Bausch & Lomb Optical Co.*

488. Oil Quenching
Catalog V-1146 gives detailed information on self-contained oil coolers, together with easy selection tables. *Bell & Gossett Co.*

489. Petroleum Refining
New booklet now available on Allegheny clean, sound, sanitary fittings for petroleum refining industry. Others in different fields furnished on request. *Allegheny Ludlum Steel Corp.*

490. Photography
Book entitled "Functional Photography in Industry" describes processes and techniques applicable to a wide range of endeavor. *Eastman Kodak Co.*

491. Polishing and Buffing
Bulletin entitled "Acme Straightline Automatic Polishing and Buffing Machines" illustrates and describes a machine for every type of production polishing and buffing job. *Acme Mfg. Co.*

492. Potentiometers
Dynalog instruments for control of temperature, humidity, pressure, flow, etc. Details in bulletin 427. *Foxboro Co.*

493. Pyrometer
Catalog No. 80 illustrates and describes the Pyro Optical Pyrometer for quick, accurate temperature readings on minute spots, fast moving objects and small streams in a temperature range from 1400°F to 7500°F. *The Pyrometer Instrument Co.*

494. Refractories
Revised bulletin entitled "Lumnite Refractory Concrete" discusses latest available information on refractories and heat-resistant concrete. *Lumnite Div., Universal Atlas Cement Co.*

495. Refractories
New 4-page leaflet No. 312 discusses properties and applications of Taylor Sillimanite (Tasil) special refractories. *Chas. Taylor Sons Co.*

496. Rust Preventives
80-page color illustrated, conveniently indexed book discusses the various No-Ox-Id rust preventives for every industrial purpose. In addition, this booklet contains general information of value to anyone concerned with the prevention of corrosion. *Dearborn Chemical Co.*

497. Rust Remover
New bulletin 909 describes new process for removing oil and grease and also Diversey Everite for all descaling and de-rusting operations. *Diversey Corp.*

498. Sawing
Bulletin 2-MP illustrates the circular sawing of metals, and new automatic triple-chip method for sawing stock up to 6" accurately without burrs. Write for details on company letterhead. *Motch & Merryweather Co.*

499. Saws
Catalog 49 describes complete line of metal-cutting saws, covering 35 models in 10 basic types, and including the world's fastest automatic production saw, the largest hydraulic hack saws, and some of the most widely used small shop saws. *Armstrong-Blum Mfg. Co.*

500. Slitting Lines
74-page book describes the multiple rotary slitting lines. Prepared in two parts: part 1 gives basic information on design selection and operation of [illegible] and slitting lines. Part 2 contains specif[illegible], capacity tables and other data on Yod[illegible] [illegible]rap choppers, coilers and recoilers. *Yoder Co.*

501. Steel Mill Equipment
Attractive bulletin illustrates complete line of hydraulic presses, steel mill equipment, iron and steel rolls, grinding machines, steel castings and jaw crushers. *Birdsboro Steel Foundry & Machine Co.*

502. Steel Selector
Handy, clearly printed, easy-to-use tool steel selector will be furnished on request. *Crucible Steel Co. of America.*

503. Steel, Stainless
New illustrated booklet, "Stainless Steel for Heat Resistance", presents a concise discussion of the properties of stainless steel and outlines the proper grades to use for parts subjected to heat. *Armco Steel Corp.*

504. Steels, Heat Treated
New bulletin gives engineering data on Rycrome and Nikrome "M", two high performance alloy steels supplied in the heat treated condition, ready for use in heavy-duty applications. *Joseph T. Ryerson & Son, Inc.*

505. Steels, Stainless
Weekly lists with analyses of all plates in stock will keep you regularly informed on latest data. *G. O. Carlson.*

506. Tempilstiks°
"Basic Guide to Ferrous Metallurgy", a plastic laminated wall chart in color, furnished on request. *Tempil° Corp.*

507. Thermocouples
A new 34-page catalog, Reference H, will furnish complete data on thermocouples, quick-coupling connectors, thermocouple wire, lead wire, protection tubes, etc. *Thermo Electric Co.*

508. Thermocouples
Catalog 59-R tells complete story about use of Chromel-Alumel couples and extension leads. *Hoskins Mfg. Co.*

509. Welding
New bulletin entitled "ABC's of Welding High Tensile Steels" discusses the use of low hydrogen electrodes in simple question-and-answer form. *Arcos Corp.*

510. Welding, Spray
New hard-facing method using the Colmonoy Spraywelder described in bulletin along with various accessories for different operations. *Wall Colmonoy Corp.*

511. Welding, Stainless Steel
Valuable information about welding of stainless steel with Airco stainless electrodes contained in new catalog ADC-650B. *Air Reduction Sales Co.*

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METAL PROGRESS

7301 Euclid Avenue, Cleveland 3, Ohio

June, 1950

429	447	465	483	501
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Please have literature circled at the left sent to me.

Name ______________________ Title ______________

Company ______________________________________

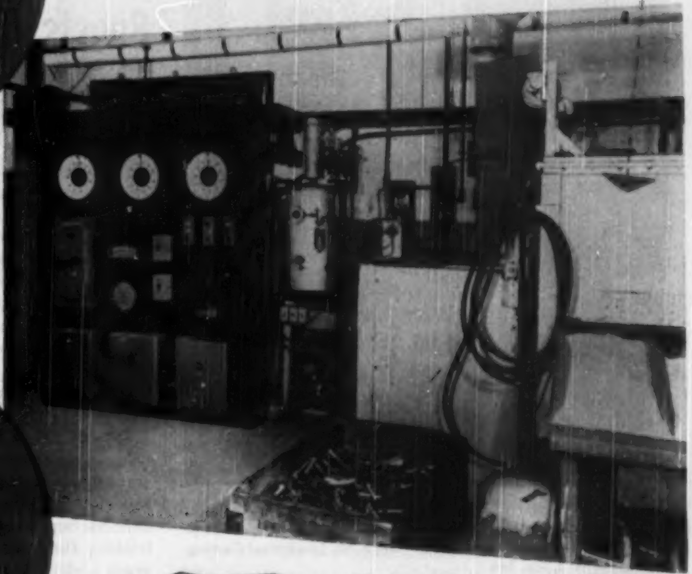
Products Manufactured ___________________________

Address _______________________________________

City and State __________________________________

Postcard must be mailed prior to September 1, 1950— Students should write direct to manufacturers.

HAYES FURNACE *plus* *ElectroniK* CONTROL



equals BETTER BOSTITCH STAPLERS

PRODUCTION-WISE manufacturers are incorporating up-to-date equipment in their cost reduction programs . . . and are giving it all the benefits of modern, function-fitted control.

Typical is the case of Bostitch, Inc. of Westerly, Rhode Island. The base plate and core of the Bostitch Model B8 Stapler are case-hardened precision stampings of mild steel. Their mass production heat-treatment is a critical operation . . . effectively and economically handled with a Hayes type CS400 reciprocating hearth furnace and *ElectroniK* control.

Individual *ElectroniK* indicating controllers serve each of the three temperature zones and maintain extremely uniform heats. Production, averaging 8,000 perfect pieces per day, is economical and entirely automatic. Such dependable performance is being repeated by *ElectroniK* indicating and recording controllers throughout the metals industry . . . paying off in real dollars and cents savings.

Call in your local Honeywell engineer for a discussion of your application. He is as near as your phone! MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, 4503 Wayne Ave., Philadelphia 44, Pa. Offices in more than 80 principal cities of the United States, Canada and throughout the world.

COMMERCIAL • RESIDENTIAL • INDUSTRIAL
WORLD'S LARGEST ORGANIZATION FOR ADVANCED INSTRUMENTATION AND CONTROL

Honeywell
BROWN INSTRUMENTS

FOR METAL PROCESSING

Here's more proof that Lumnite* Concrete Cuts Costs, Saves Time!

Car top made with Lumnite Refractory Concrete entering annealing furnace. Withstands rough treatment, thermal shock of quick quenching after temperatures up to 1700°F. St. Louis Steel Casting Company, St. Louis, Mo.

Core Oven Floors in same plant are made of adaptable Lumnite and crushed firebrick grog. Floors are still in good shape after 7 years' continuous service.

Change to Lumnite Refractory Concrete Boosts Car-Top Life from 6 months to 8 years

Car tops withstand constant rough handling, terrific thermal shock . . . time saved, costs cut. In this plant, car tops carrying heavy metal castings into annealing furnaces failed to stand up for more than six months. Handling these heavy castings subjects the cars to severe punishment. Operating procedure exposes them to terrific thermal shock: cars are in the furnace for hours at 1700°F. Then they are pulled out in the open to cool. In quenching cycles, cars are in the furnace at temperatures rising to 1600°F., then drawn out and quenched from 5 to 10 minutes and immediately sent back into the furnace. Such cycles are usually repeated 6 or more times.

Working with Lumnite field experts, plant officials developed a car top made with a 3″ layer of insulating concrete using vermiculite and haydite aggregate, and a 7″ top slab of Lumnite and crushed firebrick aggregate. Officials hoped these car tops would last 18 months—thus tripling their life. Instead, they have already lasted 8 years under the rugged handling and thermal conditions outlined above . . . and are still in serviceable condition!

The adaptable refractory: Refractory Concrete made with Lumnite calcium-aluminate cement and selected aggregates may be cast in place in exact sizes, shapes and thicknesses desired. Monolithic construction gives maximum durability, reduces outage time for repairs. Just think of the time and cost saved on this job alone! When repairs are needed, they may be made quickly and easily overnight, because Lumnite reaches service strength in 24 hours or less. Always keep a supply of Lumnite cement on hand. Whether your operation calls for car tops or not, you may well profit from the time-and-cost-saving properties of adaptable Lumnite. Write today for further information to Universal Atlas Cement Company (United States Steel Corporation Subsidiary), Chrysler Building, New York 17, N. Y.

SPECIFY CASTABLE REFRACTORIES MADE WITH LUMNITE

"LUMNITE" is the registered trade mark of the calcium-aluminate cement manufactured by Universal Atlas Cement Company.

MP-L-29

A UNIVERSAL ATLAS PRODUCT

LUMNITE® FOR REFRACTORY CONCRETE

"THE THEATRE GUILD ON THE AIR"—*Sponsored by U. S. Steel Subsidiaries—Sunday Evenings—NBC Network*

*I*n medieval times, a coat-of-arms had an importance that could not be overestimated. It was granted as a personal badge, signifying the attributes and accomplishments of its proprietor—and as such was respected thruout the civilized world. It had no duplicate.

In turn, the emblem imposed upon its owner a responsibility for maintaining an enviable reputation—a condition which stimulated general confidence in him.

Times have changed, but not all *things.* The sense of sanctity of an emblem is prevalent today as it was hundreds of years ago. That is why we take such pride in our trademark: NICHROME.

It is evidence of our accomplishment; our unique, personal badge — respected everywhere. Granted solely and wholly to us by the United States Patent Office over forty years ago, it symbolizes a series of superb electrical heat and corrosion-resistant alloys (developed and produced *only* by Driver-Harris Company) which today is serving industry all over the world.

Yes, there are other excellent heat and corrosion-resistant alloys, but *only one* NICHROME—the product of exclusive Driver-Harris knowledge and techniques.

We are well aware of our obligation to maintain its reputation, both here and abroad. In fact, such obligation is an inspiration to give of our best—now, tomorrow, and always.

FIFTIETH ANNIVERSARY

Nichrome* is manufactured only by

Driver-Harris Company

HARRISON, NEW JERSEY

BRANCHES: Chicago, Detroit, Cleveland, Los Angeles, San Francisco,
Manufactured and sold in Canada by
The B. GREENING WIRE COMPANY, LTD., Hamilton, Ontario, Canada

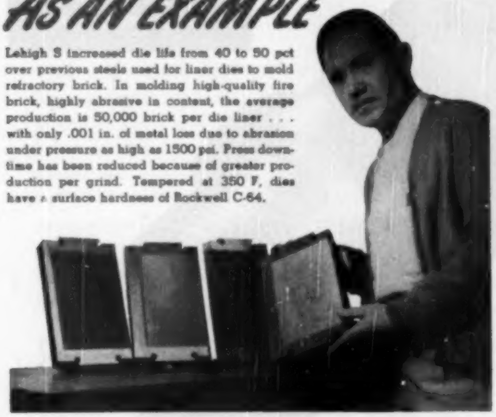
**T.M. Registered in United States Patent Office by Driver-Harris Company August, 1908*

LEHIGH S

A Tool Steel that's engineered for the utmost wear resistance

AS AN EXAMPLE

Lehigh S increased die life from 40 to 50 pct over previous steels used for liner dies to mold refractory brick. In molding high-quality fire brick, highly abrasive in content, the average production is 50,000 brick per die liner . . . with only .001 in. of metal loss due to abrasion under pressure as high as 1500 psi. Press down-time has been reduced because of greater production per grind. Tempered at 350 F, dies have a surface hardness of Rockwell C-64.



Lehigh S is your choice when you need the ultimate in wear-resistance. It assures maximum tool life under extremely abrasive conditions. Lehigh S is the oil-hardening type of high-carbon, high-chrome steel. It has very low distortion during heat-treatment . . . and the highest hardness of all our die steels; it has deep-hardening properties and high compressive strength.

Lehigh S is an old favorite with experienced toolmakers. Over and over again they choose it for tools that blank, cold-trim, and cold form; punches and deep-drawing dies; rotary slitting cutters, forming and bending rolls; shear blades and liner dies.

Give Lehigh S a trial on your jobs where wear-resistance is a big problem. You'll find it's a steel that wears and wears. Get full facts now from our nearest sales office or Bethlehem tool steel distributor.

HEAT-TREATMENT OF LEHIGH S

	C	Cr	V
Typical Analysis:	2.05	11.75	0.60

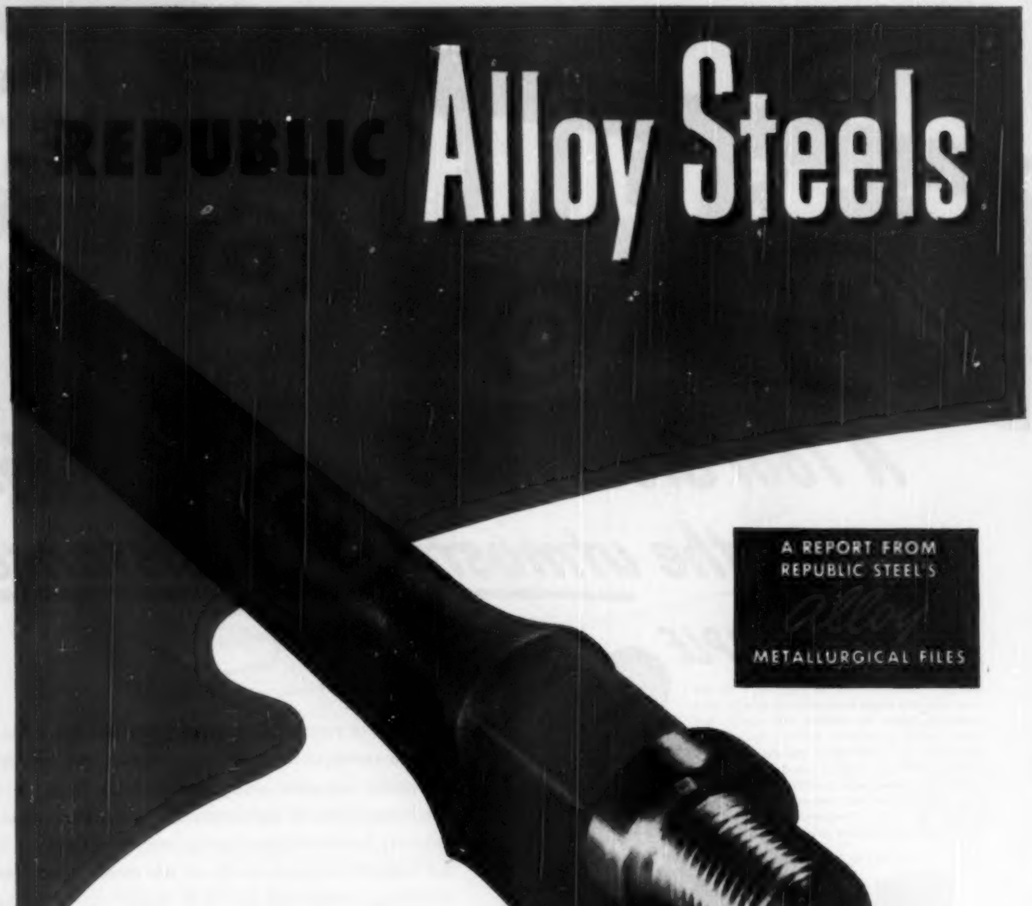
Annealing: 1625 F, furnace-cool, 241 Brinell
Preheating: 1200 to 1250 F, prior to hardening
Hardening: 1800 F, oil-quench
Tempering: 400 F, for maximum wear
925 F, for greatest shock-resistance
(Rockwell C hardness of 58 to 63)

BETHLEHEM STEEL COMPANY
BETHLEHEM, PA.
On the Pacific Coast Bethlehem products are sold by
Bethlehem Pacific Coast Steel Corporation
Export Distributor:
Bethlehem Steel Export Corporation

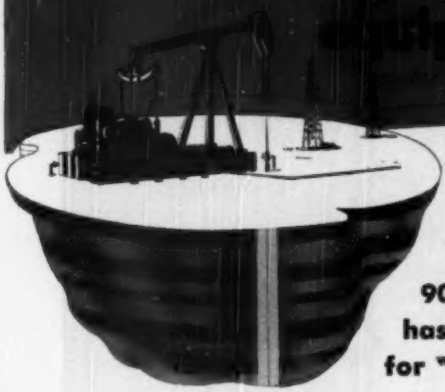
BETHLEHEM STEEL

ULTRASONIC TESTED

Bethlehem Tool Steel


REPUBLIC Alloy Steels
A REPORT FROM
REPUBLIC STEEL'S
Alloy
METALLURGICAL FILES
Photo courtesy
The S. M. Jones Co.,
Toledo, Ohio
FIELD
MILL
LABORATORY
3
DIMENSION
Metallurgical Service
. . . combines the extensive experience and coordinated abilities of Republic's Field, Mill and Laboratory Metallurgists with the knowledge and skills of your own engineers. It has helped guide users of Alloy Steels in countless industries to the correct steel and its most efficient usage . . . IT CAN DO THE SAME FOR YOU.
Other Republic Products include Carbon and Stainless Steels — Sheets, Strip, Plates, Pipe, Bars, Wire,

. . . increase Yield Strength 30% for prominent oil well equipment manufacturer



. . . Sucker Rods for Heavy-Duty Deep Well pumping now GUARANTEED to 90,000 p.s.i.—whereas the previous high has been 70,000 p.s.i.—another triumph for *"the right steel in the right place"*

With many wells ranging from 6,000 to 12,000 feet in depth, pumping places a tremendous strain on the sucker rod string entrusted with bringing the oil to the surface. Each slender sucker rod unit—only 25 or 30 feet long and ⅝" to 1" in diameter—must be capable of supporting the multi-ton weight of the entire string . . . must carry the weight of the oil rising to the surface . . . must stand up under the constant whipping and reversing action of pumping.

For more than five years, Republic's field-mill-laboratory metallurgical team has worked with this manufacturer's own metallurgists—to produce a stronger, longer-lasting sucker rod for deep well pumping.

The result? The "right steel in the right place" not only increased yield strength by a phenomenal 30%, but it did more. Coupled with this added strength are great endurance and high fatigue resistance. And because the steel is used in its normalized and tempered condition, there is no sacrifice in needed corrosion-resistance.

This is but one of many important oil field applications in which Republic Alloy Steels and 3-Dimension Metallurgical Service have resulted in improved performance . . . lower production costs . . . higher productivity. What has been accomplished here can reasonably be done in *other* applications, in *other* industries.

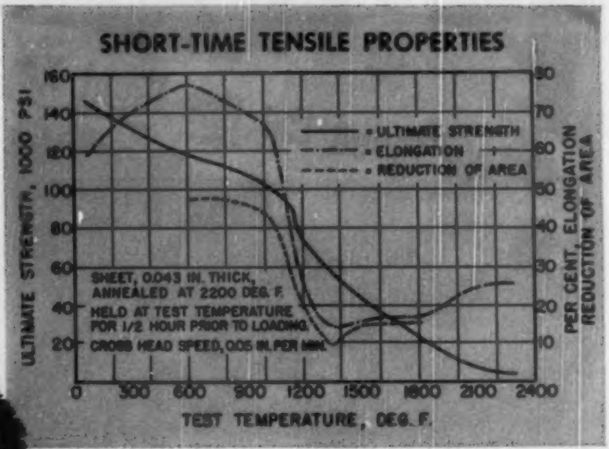
Are you using "the right steel"? Why not call on Republic's 3-Dimension Metallurgical Service to work with your own metallurgists toward finding it—and with it, new economies and new profits. Call your nearest Republic representative today.

REPUBLIC STEEL CORPORATION
Alloy Steel Division • Massillon, Ohio
GENERAL OFFICES • CLEVELAND 1, OHIO
Export Department: Chrysler Building, New York 17, N.Y.

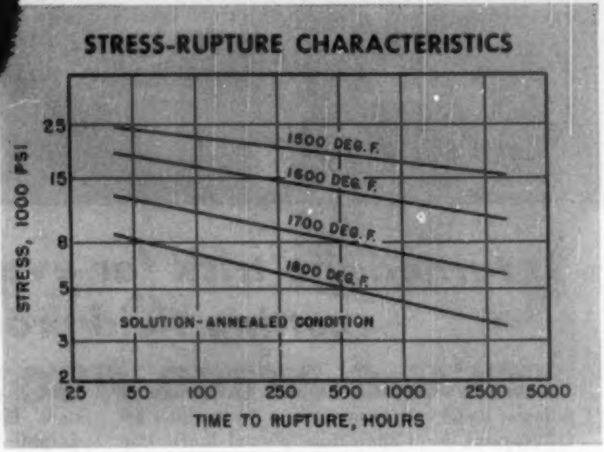
Republic
REPUBLIC STEEL
ALLOY STEELS

Pig Iron, Bolts and Nuts, Tubing


LOOKING FOR WAYS TO CUT HEAT-TREATING COSTS? . . . TRY FIGURING WEIGHT OF EQUIPMENT AGAINST APPLIED LOAD
BOX WEIGHT
LOAD WEIGHT
Cast Alloy Box
BOX WEIGHT
LOAD WEIGHT
Welded Alloy Box



HAYNES
TRADE-MARK
Alloy No. 25



STRONG up to 1800°F. without aging

DUCTILE at room temperature

HAYNES alloy No. 25 is a new wrought high-temperature alloy that has exceptional mechanical properties at temperatures up to 1800 deg. F.—*in the fully annealed condition without subsequent aging*. Yet this alloy is *easy to fabricate* because it has excellent ductility at room temperature. This combination of properties makes HAYNES alloy No. 25 an ideal material for the construction of highly stressed parts that must operate at elevated temperatures.

This latest addition to the series of HAYNES high-temperature alloys was developed as a wrought material to withstand a minimum stress of 6,000 lb. per sq. in. for 100 hours at 1800 deg. F. It is available as sheet, plate, bar stock, and tubing.

Consult our nearest office for engineering data and assistance in solving your high-temperature problems with HAYNES alloy No. 25. Physical and mechanical properties of the other 9 HAYNES high-temperature alloys are given in tabular and graphic form in the booklet, "HAYNES Alloys for High-Temperature Service." Data on short-time tensile properties, stress-rupture, creep test, endurance properties, and fabrication procedures are included. Write to Haynes Stellite Division, UCC, 725 S. Lindsay St., Kokomo, Ind.

Haynes Stellite Division
Union Carbide and Carbon Corporation
UCC
General Offices and Works, Kokomo, Indiana
Sales Offices
Chicago — Cleveland — Detroit — Houston
Los Angeles — New York — San Francisco — Tulsa

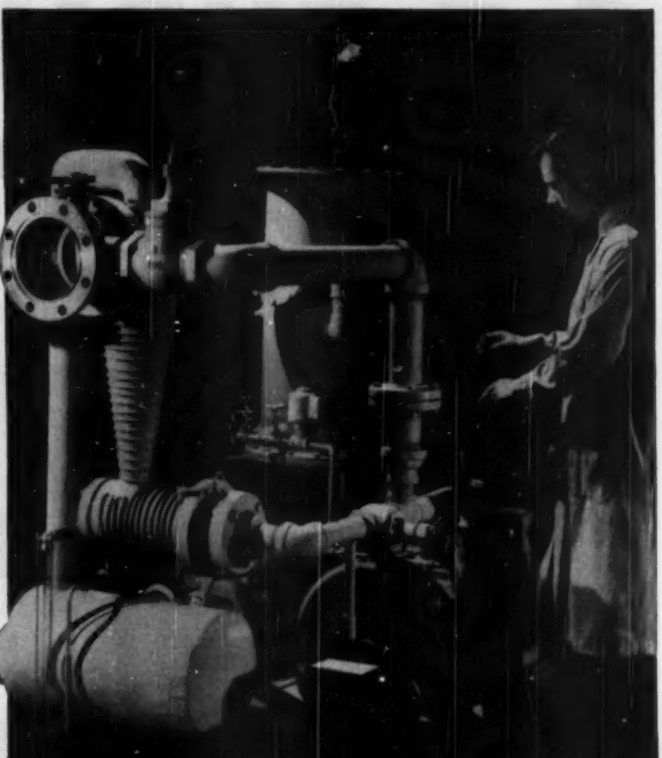
HAYNES
TRADE-MARK
Alloys

DPI

can give you

"High Vacuum in a Package"

for your specific requirements



This KB-150 Exhaust Unit can evacuate 150 liters of gas per second at a pressure of 100 microns of Hg. It attains an ultimate vacuum of 1 micron. Included are a DPI KB-150 Oil Ejector Pump, a Kinney DVD-8810 Mechanical Pump with electrically heated water separator tank, a roughing line to enable the mechanical pump to do the initial evacuation, two DPI Pirani Gauges, and a DPI Quarter-Swing Valve.

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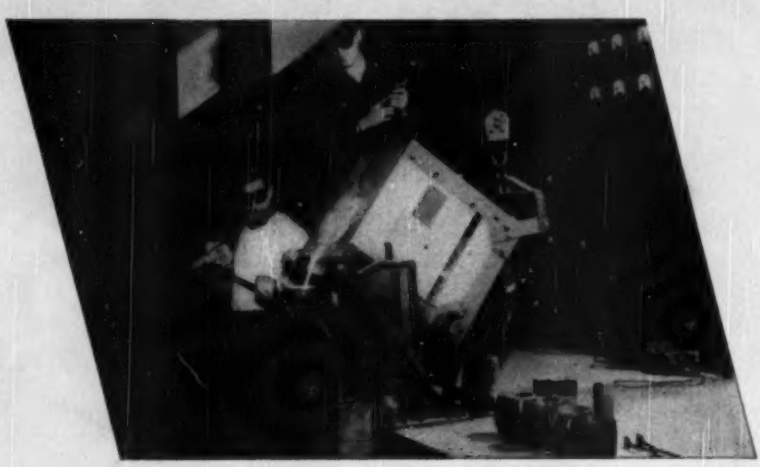

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Worcester 6, Massachusetts

Metal Progress

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Critical Points

By The Editor

A SPATE of publicity in the popular prints and business press about future supplies of iron ore for the U. S. steel industry, as well as some important official pronouncements, warrant a little comment supplementary to that already printed in *Metal Progress* (February 1949) about "The Steel Industry in Transition". It was there argued that the taconite rock of the Lake Superior iron ranges, concentrated and pelletized, would be the best and safest replacement for the open-pit Mesabi ore since *(a)* the general methods for concentration have been well-proven by 30 years of large-scale operations in the American copper industry, *(b)* it utilizes present transportation facilities wholly within our territorial limits, *(c)* it will serve our present steel producing centers, and *(d)* its added cost will likely be regained by economies in blast furnace smelting. The merit of these considerations seems established by the large use of similar concentrates from Jones & Laughlin's Benson mine in the Adirondacks, by the very extensive laboratory work currently being financed by several steel companies in the Lake region, the announced intention of Oglebay Norton & Co. to build a mill at Beaver Bay, Minn., to produce 10 million tons of concentrates yearly, and U. S. Steel's allocation of $200 million for a similar concentrator of somewhat larger capacity.

Ore for Pittsburgh's furnaces

Meanwhile the approaching exhaustion of our bonanza iron deposits is marked by an increasing proportion of foreign ore imported into the United States. Three million tons in 1946 have grown to 8.3 in 1949, consisting of 1,500,000 from Ontario, north of Lake Superior, 2,500,000 from Chile, and much of the rest from Sweden. That these imports are to be greatly extended seems likely, since very important deposits have been located in Venezuela and in Labrador, and mining rights acquired by large American corporations.

In Venezuela, Bethlehem Steel Corp. (already relying on Chilean ore for its plant at Sparrows Point, near Baltimore) acquired rights more than 20 years ago to mine a deposit at El Pao containing 50 to 75 million tons of very high grade hematite, and shipments are about to begin over 30 miles of railroad, thence 200 miles down the Orinoco River by barge, and 2500 miles by ore boat to Sparrows Point.

Surveys conducted during the last four years by U. S. Steel Corp. some 75 miles southwest of Bethlehem's operations located a mountain 2000 ft. high and comparable in area to the Hull-Rust-Mahoning group of open pits at Hibbing, containing an ore body officially described as "of sufficient size and quality to affect materially the iron ore supply of America", and unofficially reported to contain at least 500 million tons analyzing 57% iron (natural) or 63% (dry). The next job is to get it out, requiring either a 275-mile railway (or a 100-mile railway plus 200-mile river barge), an ocean terminal on the Caribbean Sea, and a fleet of ocean-going ore boats. As John G. Munson, vice-president of U. S. Steel, recently said, "Our problem in Venezuela is one of financing the development of the property itself, and the methods to be used in bringing out the ore."

One other consideration seems to be discounted, namely, that large foreign imports of iron ore will inevitably draw the steel-producing plants toward the seaboard — exactly opposite to the inland dispersal of strategic industries wished by the armed forces. (Note the announced purchase of a large industrial tract on the Delaware near Trenton by U. S. Steel Corp. "suitable for an integrated steel plant".) It might be well for the raw materials men of the steel industry to confer with those of the aluminum industry on the hazards of wartime transport across the Caribbean. Likewise, if, as and when the Venezuelan ore deposits comprise a vitally important proportion of the American necessities, the best way for Venezuela to lose its independence would be to acquire a government unfriendly to us in some future emergency.

It would seem that the Labrador deposits are politically more desirable, and thus may be the last nudge required to bring about that international undertaking known as the improvement of the St. Lawrence waterway. The existence of a belt of iron-bearing rock, some 40 miles wide by 300 miles

long across the interior of the Labrador peninsula, has been known for more than 50 years, according to M. W. Goodwin, of the Canadian Bureau of Mines. Inaccessible until aircraft passenger and freight service could be established, this region has now been prospected for 20 years. The most consistent activity has been a joint effort of the Canadian firm of Hollinger Consolidated Gold Mines, Ltd., and the American coal and ore firm of M. A. Hanna Co. In their concession some two dozen "commercial" ore bodies have been proven by drilling in an area 90 miles long by 3 miles broad; they range in size up to 50,000,000 tons, and total about 355 million tons of ore containing 57 to 61% iron (dry analysis). Geologically the area is quite similar to the Mesabi range; the mineralized bodies are generally in ridges and under glacial drift not too deep to be moved by bulldozers. A hydroelectric station at Eaton Canyon, 50 miles distant, can be installed to develop 500,000 hp. The provincial governments get a royalty of 5% of net

Labrador iron ore

profits plus $100,000 annual rental, but the great advantage Canada can derive from a large export of ore to the United States is to correct the unbalance of trade, now so heavily in our favor that the Canadian dollar is worth only 90¢ in New York.

The ore evidently is there. All that is necessary is to get it out! Again the problem is chiefly financial. First must be a 350-mile railroad, already located. Next are ore docks at Seven Islands on the Gulf of St. Lawrence. Finally is the canalization of the river itself so ore boats can reach the Great Lakes. (The water distance from Seven Islands to Lake Erie is about the same as from Duluth to Lake Erie.) As to weather, the winter is somewhat more severe than in upper Minnesota; all mining operations will be a summer's affair and probably most of the inhabitants would go south for the winter.

All-in-all, the situation is not so different from the one existing in the American iron ranges that it would offer much resistance to Canadian ingenuity.

Six-Inch Drill in Operation, Prospecting Iron Ore Deposit in Labrador-Ungava Concession of Labrador Mining & Exploration Co. Photo by Canadian National Film Board

OF ALL the manifold activities shown by Bruce Hamilton, metallurgist at Atlas Steels Ltd. in Welland, Ontario, associated with their production of diverse electric furnace steels in the usual commercial shapes, the one that most intrigued The Editor (a mining engineer by degree) was the manufacture of hollow steel for rock drills. Here is a specialty that demands the best that metallurgists can give it, for it must withstand about the ruggedest mistreatment imaginable. Drill steel is, of course, only one element of a complete rock-drilling machine, which as a unit has been developed primarily by Americans like Burleigh, Ingersoll, Sergeant, Rand and Leyner, into a device of constantly greater power, yet constantly lighter weight and improved reliability. To appraise this essential unit in mining compare two instances drawn from the record books: According to the Roman historian Pliny, Emperor Claudius desired the drainage of a lake, and 30,000 men labored 11 years to drive the required 3½-mile tunnel. Nineteen hundred years later, 100 miners removed the same amount of rock from a similar drainage tunnel in Cripple Creek in a little less than one year. . . . . Essentially, a blasting hole is drilled in rock now the same as it always has been: A rod of steel has a chisel edge or crosswise edges forged and hardened on one end; this sharpened end bites into the rock as the other end is hammered. The air drill's hammer strikes a 20 ft-lb. blow 2000 times a minute! Earlier drilling machines could readily drive an up-hole, for the rock chips fall out, but their use for horizontal and down-holes waited for hollow drills to deliver a flush of water to the bit, and for 15 years tool-steel makers struggled with the problem of making 60-ft. pieces of 1-in. hexagon with a $\frac{3}{16}$-in. hole down its axis. The Europeans rather favored the scheme of piercing a billet, rolling it down over mandrels as far as possible and then finishing with the hole empty. This gave a hole with a weak, decarburized surface. Americans rather favored the scheme of drilling a billet, plugging the hole with fine sand, rolling to size, and then blowing out the sand. This was cheaper, but in addition to decarburization, the hole was rough, dirty, and full of stress raisers. In either event, fatigue failures, starting at the bore, were distressingly frequent. The miner blamed the steel and the steelmaker blamed the miner, and broken steel continued to litter the workings. . . . . Finally, in 1927, Harry Brearley, the inventor of stainless steel, patented the method now used at Atlas Steels. Square billets are drilled axially with a 1½-in. hole, and a tight-fitting round of austenitic manganese steel pressed in, and its ends upset, protruding about 2 in. This composite billet is then heated and rolled to a bar of correct size and shape, 50 to 60 ft. long. It is nicked and broken near each end — that is, the outer steel breaks, the inner "wire" holds. These two loose ends are then pulled in a draw bench; the austenitic wire, by virtue of its property of general elongation, contracts in diameter and frees itself completely, end to end. Result: a smooth inside hole, entirely free from decarburization. . . . . Atlas makes several grades of hollow drill steel. One is the traditional 0.80% carbon, 0.25% manganese steel, silicon killed — the analysis the old crucible process was best adapted to. It is still used for small operations where a blacksmith upsets and hardens the bits. The detachable bit (now popular) requires a steel of even better fatigue resistance; since high surface hardness is no longer necessary a steel with 0.35% carbon, 3.0% nickel is recommended. Chisel-type tungsten carbide bits must work even longer in high-power air hammers; drill steel developed for conventional drilling in extra hard rock seems to work well with them; it is a 1.0% carbon steel with 1.0% chromium and 0.30% molybdenum.

Hollow drill steel

THE POLITICAL aphorism, "If you can't lick 'em, join 'em", has an analogue for metallurgists: "If you can't pull it, push it." Confronted with some cracked stampings or pressings, that alternative is too frequently forgotten. Not so at Tube Turns, Inc., of Louisville, Ky., where remarkable things are done to seamless tubing by pushing it into shape — or, at worst, giving it a big push and a little pull. Francis Klayer, metallurgical engineer, piloted The Editor through the forging plant and pipe shop and opened his eyes. Aircraft engine cylinder hoods of remarkably intricate design are pushed into shape in huge headers. Pipe fittings, especially bends and tees (with chamfered ends for welding) are made in all sorts of alloys by most remarkable methods — not new, but nevertheless extraordinary, wherein the heated pipe is pushed over a curved mandrel by such art that it comes out as a forged part of uniform wall thickness. . . . . "Push-me pull-you" tactics are employed in making tees. The routine is as follows: Cut short lengths; flatten slightly into an oval pipe; drill a side hole on the long axis; heat differentially — pretty hot around the side hole, mildly elsewhere; slip into hydraulic press with top and bottom dies curved to proper final outside diameter of tee; place a conical plug inside pipe, nesting in the drilled hole;

Push it into shape instead of pulling it

key plug to a pull rod extending upward through the bottom die; squeeze pipe from oblong back to round at the same time plug is pulled downward, expanding hot metal into a proper cavity in the bottom die, thus forming the side outlet of the tee. Dimensions, temperature, rate of push on main dies, rate of pull on outlet plug, all are coordinated so metal is pushed into place and all portions of this fitting also have uniform wall thickness. . . . . Metals made into pipe fittings of this sort vary from steel to nickel and aluminum, some 40 alloys in all; sizes vary from ¾ to 12-in. fittings — even up to 30 in.; prices accordingly. Some of the king sizes run into big money — for example, a large-diameter stainless steel (18-8), long-radius, 180° turn is catalogued at nearly $2000.

VISITING in Hamilton with James G. Morrow ●, metallurgical engineer of The Steel Co. of Canada, Ltd. (currently president of the American Society for Testing Materials), observed and discussed such topics as raw materials, rapid steel refining, the still more rapid manufacture of tinplate, and matters of even more generality. It was here in Hamilton, in 1942, that the use of oxygen for speeding the melting and refining of openhearth steel was converted from the talk stage to the do stage. Making well over one third of Canada's three million tons of steel, Stelco's Hamilton operation is a complete refutation of the ancient illusion that a small industrial region can be most economically served by a multiplicity of small metallurgical plants. Stelco even possesses that most prolific of machines, a modern continuous strip mill, complete with cold rolling department, electrolytic tin line, and the small army of good looking girls, flopping the sheets over, one by one, looking for blemishes. If some electronic gadget were installed to replace them it would indeed be a news-worthy innovation, although it would undoubtedly lower the amenities of the steelworkers' life. One interesting variant *can* be reported, though, and that is the use of an adjoining plate mill, constructed early in the war to serve Canada's shipbuilding program, as a source of slabs for the sheet mill — really plates ¾ to 1¼ in. thick of proper width and length. . . . . Extensive mining operations were in progress on the slag dump — a large acreage stolen from Lake Ontario. Bulldozers shove the top layer of slag aside and spread it out, then a crawler crane equipped with magnet feels it over. The little stuff is trucked to a screening plant and again worked over by magnets. The big pieces uncovered are dragged to a skull cracker; sometimes they must be cut apart with oxygen lances or blasted open. Most of the reclaimed material is resmelted in the blast furnace rather than used as openhearth or bessemer scrap, so it must be small enough to go through the charging bells handily. Even in the blast furnaces, about 10% of the burden is close to the metallurgical limit.

Stelco of Canada

PHILOSOPHIZING somewhat on the conditions existing in a free country which permits a 1,100,000-ton steel mill to grow up from nothing within 40 years, our luncheon thoughts turned to the peculiar pyramiding effect of technological advances and economic progress. Only a few days before appeared a statement by the president of one of America's national labor unions, which contained the hoary fallacy that mechanization destroys jobs — whereas the fact, proven by the world's history since the industrial revolution, is that for every job a machine destroys it creates one-plus. . . . . In this connection it may be remarked that truthful statistics — those that mean what they purport — comparing productivity per worker decade by decade are hard to come by. Figures from a large integrated concern like the U. S. Steel Corp. come nearest to statistical accuracy. R. C. Cooper, its vice-president for industrial engineering, recently gave these data (among others) in his testimony before the Joint Committee on the Economic Report to Congress:

Machines make jobs

Year	Tons Shipped	Labor in Man-Hours	Man-Hours per Ton
1934	6,501,000	198,006,000	30.5
1935	8,086,000	228,920,000	28.3
1936	11,905,000	309,823,000	26.0
1946	15,182,000	290,741,000	19.2
1947	20,242,000	353,778,000	17.4
1948	20,655,000	368,148,000	17.8

Man-hours per ton are evidently at a considerably lower level now than before the war, yet employment has almost doubled in this period of intense mechanization. However, Mr. Cooper points out that productivity is influenced by many factors other than mechanization, notably volume of production, changed proportions in grades, shapes and customers' requirements, managerial skill and improved methods, quality of raw materials, employees' morale. . . . . One might plausibly assume that the above figures are fairly representative of manufacturing industries whose product closely resembles that of 15 years ago. Such things considered, it would be as naive as a technocrat to claim that job opportunities and personal well-being in America are less now than in 1935, and that this is due to labor-saving devices. ●

Metallurgical Problems in Oil Well Drilling and Petroleum Production

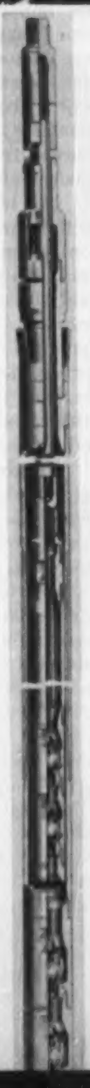
By George W. Whitney
Chief Metallurgist
and Morton Spar
Metallurgist
Emsco Derrick & Equipment Co.
Los Angeles

FEW, if any, mechanical operations demand greater durability of equipment than the drilling of oil wells. The requirements have become more exacting as the depth of well has increased. Only 20 years ago, 9000-ft. wells were a novelty; the first 15,000-ft. hole was drilled in 1938; and last year the 20,000-ft. mark was exceeded. At great depths, the man-hours spent in removing and running tools in the hole may exceed the time spent in making the hole. In a recent well in California, 18,500 ft. of hole was made in 2052 hr., during which time the crews made 185 round trips in and out of the hole to change tools and other equipment. At 18,500 ft., each trip involved the handling of 150 stands of drill pipe, each 120 ft. long.

All the recent trends in drilling have enlarged the metallurgist's responsibilities in selection and treatment of the metals that are used in oil field equipment. The present article is limited to a general discussion of the metallurgical problems in oil well drilling and producing equipment. These problems are diverse and since their solutions depend so greatly on the specific manufacturing limitations and economic considerations, there are likely to be several satisfactory solutions to a given problem. In any event, the metallurgical solution must be such that the cost of drilling (per foot) or the cost of crude oil (per barrel) is lowered without any increase in safety hazards.

A discussion of equipment may well start with derricks, which must be designed to carry the full load of the drilling string including the crown block, traveling block, hook, and swivel. The loads imposed during "fishing" operations have been known to collapse the derrick. Conventional derricks rated at 500 tons and portable masts rated at 400 tons are now commonplace. The portable masts with a high strength-weight ratio are the more popular where they may be used and of course present greater problems as regards materials. The use of A.S.T.M. A7 structural steel has given way to A.S.T.M. A94 structural silicon steel, which in turn is being replaced by the low-alloy structural types. Principal advantage of the alloy structurals over A94 is increased corrosion resistance and superior weldability. To fully benefit through the use of higher-strength steels requires careful welding designs, welding techniques and inspection. As derrick sections are too large and complicated to permit postheating and normalizing, weldments should be in locations where the load will be low.

Portable masts are subject to frequent raising and lowering and are, therefore, designed for rigidity. Since severe bending stresses are produced here as well as in actual drilling operations, the reliability of alloy structural steel is important in preventing failures without the use of excessively heavy members.



Derrick Equipment

Under the heading of derrick equipment are included blocks, swivels, elevators, tongs, hooks, drawworks, rotary equipment, slush pumps, power plants, kelly bushings, slips, and so on. Crown blocks designed to a capacity of over 400 tons are composed essentially of sheaves and bearings together with the supporting members. Lighter blocks may use the shaft as a bearing inner race although this practice is becoming obsolete. As loads and spans increase, this arrangement becomes unsatisfactory and large-diameter drum shafts are employed. The increased rigidity of this arrangement improves rotation characteristics of the sheaves, and the large-diameter bearings result in lower roller pressures with increased life expectancy.

Metallurgical characteristics of the sheaves are important, not only to sheave wear, but to rope wear. The use of hardenable alloy steels has eliminated groove corrugations which were a considerable factor in damage to wire lines. Of course the ratio of sheave diameter to wire rope diameter is still of crucial importance to rope life. Durability of crown blocks is promoted by adequate lubrication of bearings.

The traveling block presents the same problems as the crown block, with the added requirement of compactness. To provide free fall when not under load, this equipment is made heavy and friction is held to a minimum. Since failure of this part may mean the dropping of heavy equipment to the derrick floor, manufacturing methods must include correct design, material, welding techniques and magnetic particle inspection. Tension impact, not often found in industrial equipment, may be encountered on this part.

The swivel is connected to the traveling block by a hook, which may be integral with the block or may be suspended from the clevis of the block. Hooks are employed to minimize shock loads on the block as well as to provide easily made connections to the various tools used on the derrick floor. Ratings of swivels drop appreciably from those of blocks and derricks, since they are not subjected to the high loads encountered in setting and pulling casing or pulling stuck drill pipe. Present capacity is about 300 tons.

It is at this point that we encounter rotary motion relative to the static fluid line from the slush pump. Wash pipes designed to take wear at this point are still not wholly satisfactory although considerable improvement has been made recently. The wash pipe is a nonrotating member which is sealed on its outer surface by a packing gland. Mud pumped at high pressures through the hollow sleeve into the drill pipe tends to work into the packing gland and produces severe abrasion. Hardfacing the surface has not improved service, in terms of cost, over a carburized and hardened part. The engineering answer to this specific problem has been the design of the packing gland which maintains a positive lubrication between the gland and the metal. Further improvement of this member may be anticipated, as repairs are expensive and inconvenient.

The swivel sleeve must provide a bottom joint connection strong enough to withstand the drill pipe load. The "subs" which connect the swivel sleeve to the drill stem and the drill pipe to the drill stem must be made up tight enough so that the preload will be sufficient to prevent stand-off between faces upon application of the static load. The threads must also be hard enough to eliminate galling during make-up, a process which requires care and a suitable lubricant. To withstand high rotational speeds under heavy loads, bearings are made of deep hardening high-alloy steel.

Connected to the swivel through the sub is the "kelly". Usually square, sometimes hexagonal, the kelly is the driven member which imparts rotary motion to the drill string. The ends are upset to permit machining a suitable joint. The entire kelly is heat treated and the ends customarily hardened to a greater strength than the body. Drilling a hole through the length of a 40-ft. kelly requires steel of uniform microstructure and freedom from inclusions.

Power Transmission

Principal sources of power are steam, electric and diesel. With mobility a dominant feature of drilling rigs, diesel engines are gaining in popularity. Engine arrangements vary widely with operators but compounding of some sort is customary. Compounding promotes uniform engine wear since various elements of a drilling rig installation have different power requirements and compounding permits use of maximum power when required.

Compounding and selective transmissions are assemblies of clutches, shafts, bearings and sprockets. The use of friction clutches has eased considerably the demands on equipment by minimizing the shock on engaging members. Friction clutches are built of cast-iron parts; these must be free from porosity, which interferes with pneumatic action. The highly stressed members are usually made of alloy iron of the 60,000-psi. tensile class. Jaw-type clutches are made of cast carbon steel or alloy steel. Minimum jaw wear is produced by flame hardening of contact surfaces or by quenching and tempering to a suitable hardness.

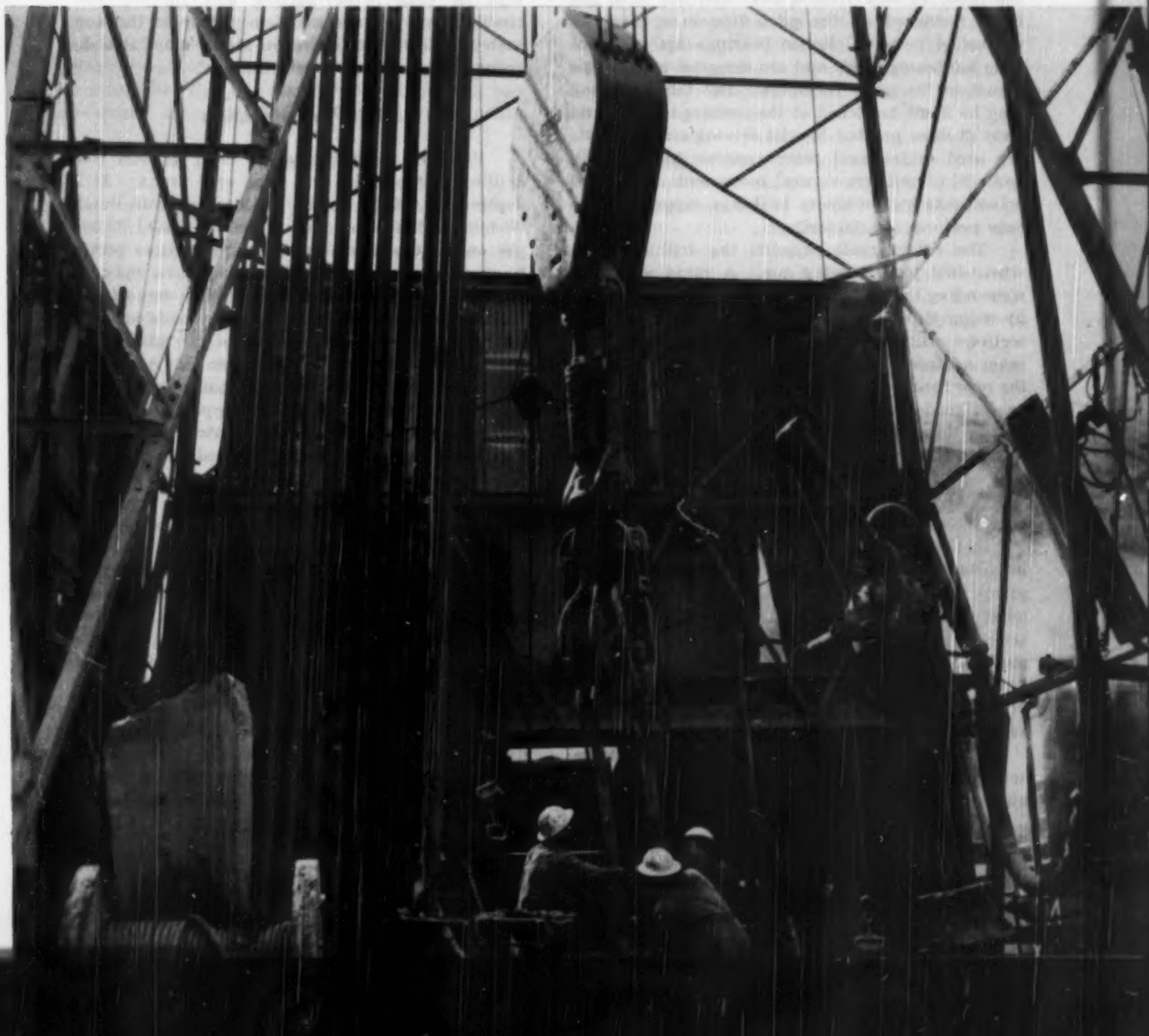
Sprockets are treated similarly to clutches. The use of small-pitch multiple-strand chain has been important in decreasing sprocket wear. Conversely, hardened sprockets have greatly improved chain life by maintaining tooth contour.

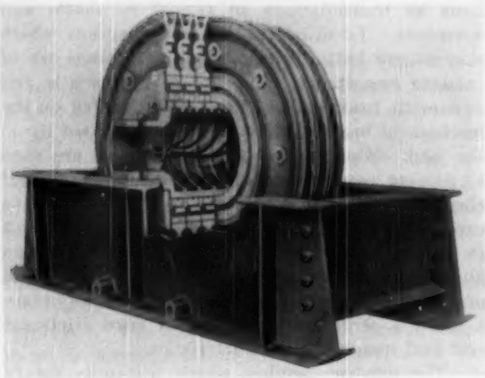
Shafts are metallurgical nightmares in that stress raisers in the form of splines, bearing shoulders, and retainer grooves occur throughout their lengths. Hardenable alloy steels are used which permit development of suitable strength and reasonable machining characteristics by mild quenching operations. These heat treatments are designed so that no straightening will be required. Every effort is made to reduce stress concentration factors by the use of fillets and undercuts. Shrink fits of bearings must be carefully controlled to eliminate failures by fatigue at points of stress concentration.

Drawworks present many of the same problems as transmissions in regard to shafts and sprockets. To utilize the high line speeds which may exceed half a mile per minute, brakes are of extreme importance. The use of hydromatic and dynamatic braking has reduced the burden on the mechanical brakes, which still must be used to set the load. Water-cooled steel brake rims are used to prevent overheating. Despite this, severe heat checking of the rim surface makes brake rims expendable. Increased cooling rates are difficult to obtain because of stuffing box limitations on allowable pressures and orifices. The metallurgical problem in connection with brake rims is to obtain a uniform structure in a steel of good frictional and heat conducting characteristics.

The driving member which transmits rotary motion to the kelly is called the "rotary machine". The gear table is fully supported on the main bearings and is driven by spiral bevel gears. Gears

Running Pipe. Swivel, kelly and bushing at right; traveling block, hook, elevator and tongs in operation





Crown Block. Principal elements shown in sectional view. Located at the top of the derrick, this block may be designed to a capacity of over 400 tons

are made of heat treated steel and the teeth are flame hardened on the pitch line in a carefully controlled pattern. Roller bearings are made of deep hardening steels and are designed to transmit thrust to the main raceways. The table bushing may be flame hardened at the corners to eliminate wear at these points. Special driving arrangements are used to transmit rotary motion to the kelly and still permit free vertical movement. Hardened rollers rotating on sleeve bushings supported in a cage perform satisfactorily.

The rotary table supports the drilling string when drill pipe is being run. A rapid means of suspending the pipe in the bushing is accomplished by using slips which are carburized and hardened sections with small pyramids machined on the inner surface. These slips move on a taper to grip the pipe firmly on the entire periphery. Slips must be designed not to damage the drill pipe and casing during this wedging action, as such damage leads to rapid failure of the drill pipe.

Slush Pumps

In modern rotary drilling, one of the most important items of surface equipment is the slush pump. Large volumes of mud under high pressure must be delivered to the bit to provide jetting action and to float the cuttings to the surface. The mud also supports the walls of the hole and prevents caving. Slush pumps are presently designed to work at pressures as high as 3500 psi. and are customarily tested at 5000 psi.

Liners, because of high pressures and abrasive action, are considered expendable. Although carburizing and hardening of the cylinder bore is frequently used, new techniques call for induction or flame hardening of alloy or carbon steels. Cross heads and guides are also subject to severe wear and various combinations of surfaces have been used to minimize friction and abrasion. Improved welding techniques permit the use of small cast steel sections for fabrication into fluid ends. By decreasing casting sizes and simplifying the sections, less porosity (which leads to wash-outs) has been encountered. The power end of the slush pump utilizes hardened herringbone gears which have proved satisfactory. The eccentric crank is supported on heavy-duty antifriction roller bearings.

In addition to the factors mentioned with regard to surface equipment, offshore drilling, particularly in the gulf country, has added the factor of extreme corrosion. No satisfactory way has yet been found to immunize the various types of equipment but it is expected that all combinations of surface treatments, protective paint coatings as well as galvanizing and sprayed zinc coatings will be necessary to minimize the corrosion. Corrosion resistant steels may also be economical for certain installations.

Drill Pipe and Joints

Probably the principal problem in deep well drilling is found in drill pipe and joints. At a depth of 20,000 ft., 4½-in. 18-lb. pipe would weigh 90 tons which would give a load of about 36,000 psi. on the top tube. Since most operators prefer to carry some of the drill collar weight on the drill pipe, to permit straight drilling, the actual load will be somewhat higher. Added tensile stresses are produced by the mud pressure. In addition to the static tensile stresses there are torsional, shock and vibration stresses. Loads are such as to indicate mechanical properties which may be obtained only by fully heat treated alloy steel. That such drill pipe is not produced is due to the requirements of straightness and freedom from residual stresses. The grades of drill pipe now used have minimum yield strengths of 45,000, 55,000, and 75,000 psi. Joint problems are ever present due to frequent making and breaking of joints with attendant wear of threads, producing poor fits which lead to fatigue failures. Where joints have been welded to tubes, or rigid joints have been produced by tapered or shrink fits, little trouble has been encountered from fatigue cracks on the pipe thread end. Unfortunately, in order to pull drill pipe, every joint cannot be permanently affixed; the string must be broken into "stands" of drill pipe in multiples that depend on derrick height. Drill pipe and joints suffer severe

abrasion and erosion from contact with the hole wall and the ascending mud. The use of hard facing in wear bands on the joints has been economical in offering some protection.

To keep the drill pipe under tension and still provide weight on the bit, drill collars are placed between the bit and pipe. These are heavy-walled hollow tubes made of heat treated alloy steel. The ends are threaded, either box or pin type, to provide make-up joints. To increase the life of the collar, affected principally by abrasion, some operators have resorted to hardfacing several rings around the surface. As with the kelly, proper microstructure facilitates boring a true hole throughout the collar length. In order to make an accurate survey of hole direction, the use of K-Monel for at least one drill collar may be practical. This enables the surveying crew to set their instruments in the nonmagnetic collar without removing the drilling string.

Drilling bits are made in great variety. Practically all modern bits are hard faced in some manner, using crushed cast tungsten carbide or similar hard facing material set in a matrix of electric weld deposit. The introduction of roller bearings on the spindles of roller-type bits has produced a very satisfactory cutting instrument.

Casing

Casing is another limiting factor in deep oil well drilling. Made in grades of 40,000, 60,000, 75,000, and 100,000-psi. tensile strength, the casing is subject to failure under combined stresses, of which collapsing forces are a major influence. Higher-strength material presents problems of manufacturing similar to those of high-strength drill pipe. Some limitation on the hardness of casing material is established by producing operations which require perforation or an actual milling cut at great depth. To improve casing, such steels as S.A.E. 4340, normalized and tempered, have been introduced.

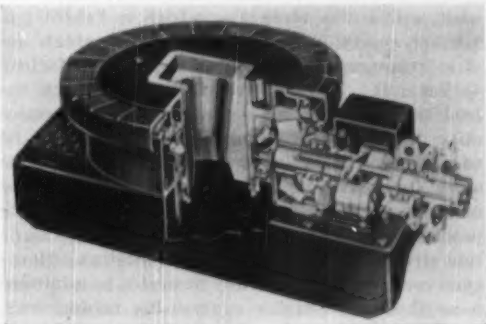
Special Items of Equipment

Numerous items with specialized material requirements have been developed for the oil industry. Typical examples are cementing shoes and gun perforators. Cementing shoes must be strong enough to withstand crushing forces encountered in field practice and still have characteristics that will permit removal by drilling and floating of the fragments. Concrete and plastics are employed here to provide the necessary drillability. Gun perforators have been designed to shoot projectiles through several strings of casing, including concrete, in order to produce from any desired oil zone when several zones are available. Explosion pressures approach 200,000 psi. in the chamber; therefore, careful choice of materials and properties developed by heat treatment is required.

Oil field chain, once considered a highly expendable item, has been improved to a gratifying degree. The use of machine-cut sprocket teeth, oil guards, pressure lubrication, and small-pitch multiple strands has decreased the demands on this type of connector. The chain itself is made to precision tolerances of alloy steels, hardened appropriately for each element. Elimination of offset designs for straight side-bar connections has also been important in promoting long life.

Wire rope is another expendable item whose durability has been increased by improved design of the various elements of drilling equipment. Made with either hemp or wire cores and in a great variety of strand designs, the principal problem is to eliminate sharp bends or kinks. High-tensile wire rope has proved adequate for the unusual depths now being explored. The highest loads occur when stuck pipe is being pulled, and derricks have collapsed before the line gave way in such an operation.

Equipment to pump nonflowing wells is considerably lighter than drilling equipment but the demands are proportionately as great. Durability of equipment is again of vital importance, as maintenance costs and the production cost per barrel of oil are subjects of constant scrutiny. Pumping problems are not limited to high operating stresses but are also concerned with corrosion and abrasion. Several methods of pumping have been developed which include reciprocating pumps activated by submerged motors or rod connections



Rotary Machine. This equipment transmits rotary motion to the kelly. The table supports the drilling string when drill pipe is being run

to surface equipment. This discussion will be limited to pumps activated through sucker rods.

Power units are principally of the walking-beam type, although a considerable number of long-stroke hydraulic units have been made. The walking beam is designed to translate the rotary motion of the power-impact unit to the required reciprocating action of the pump. General source of power is gas engines using natural gas from the field, or electric motors. The required gear reduction is obtained through herringbone or similar gear trains. Hardened alloy steels are used to promote long life since pitting of the pressure surfaces is a source of failure. Antifriction bearings are used on rotating members, the greatest load being found at the center bearing supporting the walking beam.

Sucker Rods

The sucker rod string is connected to the walking beam by a wire line carrier assembly and the "polish rod", which passes through a "stuffing box". If not carefully made up at the sockets, wire lines fail in fatigue induced by bending stresses. Polish rods, as the name implies, are bars of suitable finish and strong enough to support the loads involved. The usual finishes are ground and polished, turned and polished, or cold drawn. The materials vary from plain carbon to austenitic stainless steel. The metallurgical problems are corrosion resistance and surface finish.

The sucker rod string is a principal source of well maintenance and the stress magnitudes are similar to those for drill pipe in drilling operations. Deep well installations may produce working loads as high as 40,000 psi. This is a cyclic stress which is also influenced by corrosion, impulse and vibration factors. Various types of alloy steel and corrosion resistant materials such as K-Monel are used, with tensile strengths as high as 120,000 psi. Surface conditions, as well as alloy content, are of extreme importance in producing a satisfactory sucker rod. Notch sensitivity measured by the Izod impact specimen has long been used in evaluating this material. Considerable care must be used in forging sucker rod upsets which provide stock for machining joints and wrench flats for making up joints. Transverse folds or fillet defects produce rapid failures in service. Rods are made into strings using couplings as connectors. Hardened couplings are generally desirable to minimize wear through abrasion against the tubing wall. Satisfactory thread design and accurate machining have eliminated pin breaks as a source of trouble. Here, as in many other threaded connections, proper make-up is extremely important.

Pumps

Pumps fall into two main classifications — metal-to-metal and cup types. The metal-to-metal type is the more durable and is commonly used in deep installations. These may be made with expendable insert liners or with hardened tubes, both of which are used with hardened plungers. The elements of deep well pumps are made with high precision, since working space is extremely limited and stresses often reach the upper limits of desirability. It has been stated that the durability of the valve assembly (which consists of a ball and seat assembled in a cage) is presently the limiting factor of pump depth. The combination of axial and hydrostatic loads under the influence of impulse may produce stresses in excess of 40,000 psi. in the walls of the closed cages.

The insert-liner type of pump is made with jackets of seamless carbon steel tubing. Liners are made principally of alloy cast iron, soft or hardened. Alloy steel tubing is sometimes used to good advantage where higher hardness ranges are required. Plungers may be made of hardened cast-iron sections or more frequently of steel tubing that has been plated with hard chromium. In addition, a variety of hard special alloys is used for both plungers and liners. These may be cast into a soft steel shell. Valve cages are usually of alloy steel, hardened for strength and sometimes differentially hardened at points of extreme wear. Balls and seats are made in a great variety of materials but must be hardened to withstand impact, corrosion and fluid cutting action.

Hardened corrosion resistant pumps have been developed with some success in recent years. Galvanic corrosion must be considered in selecting materials. For instance, the use of austenitic stainless steel in conjunction with a martensitic type may produce this condition.

Conclusions

This article has mentioned in a very general manner the metallurgical problems in oil well drilling and producing equipment. Specific problems and solutions have not been freely cited as the authors feel that many solutions may be offered, depending on manufacturing limitations or economic considerations. It has become a byword that the great majority of failures are not produced by defective metal but by design or operating conditions. If this be true, then it is a metallurgical problem to recognize the differences between good and faulty design and to recommend changes that will permit the use of standard materials with optimum properties.

Stainless Steel for Television

By Arnold S. Rose
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Television picture tubes are made of ferritic stainless steel, to which is sealed the glass face plate. Expansion characteristics of the steel are important in making the glass-to-metal seal. This article describes recent changes in alloy composition that have enabled a 17% chromium iron to be substituted for the more costly 28% chromium alloy that was being used previously.

PERHAPS the most interesting feature of post-war television has been the development of large-screen picture tubes or "metal cone kinescopes". As the size of screen and number of sets have increased, the amount of metal going into kinescopes has risen to about 500 tons per month.

Ferritic stainless steel containing 28% chromium (A.I.S.I. Type 446, modified) has been providing the bulk of the alloy used. However, a recent development in the 17% chromium alloys has enabled this grade (A.I.S.I. Type 430, modified) to supplant the 28% alloy for television applications, thereby permitting a saving in cost of material and a substantial improvement in production and fabricating techniques as well.

Fabrication — When a ferritic stainless steel is used for the envelope of a metal kinescope, it is fabricated into conical shape by spinning. The cone is then sealed by means of high-temperature gas-air flames to a face plate consisting of a circular section of high-quality window glass ($\frac{7}{32}$ in. thick, 16 in. in diameter, for instance) having a uniform radius of curvature from center to edge. The neck portion of the cone is sealed in a similar manner to a lead glass, at about 2200° F. for 2 to 3 min.

Chromium irons have several desirable features for glass sealing, the most important of which is the closeness with which their thermal expansion curves match those of the glasses to which they are to be sealed. These curves are given in Fig. 1, on the next page. Because the slopes of the alloy curves are somewhat steeper than those of either the face plate or neck seal glasses, the usual design practice is to seal the alloy in such a manner that it surrounds the glass, placing the glass in mild compression.

The high chromium content of the alloys also imparts a favorable characteristic to their glass-sealing properties in that no highly specialized pretreatment is required to prepare their surfaces for sealing. The chromium oxide which is formed during application of the sealing fires is readily wetted by the glass and creates a strongly adherent bond. Further, the excellent corrosion resistance of both the 28 and 17% chromium irons and their ability to withstand high-temperature sealing are definite assets in tube manufacturing procedures.

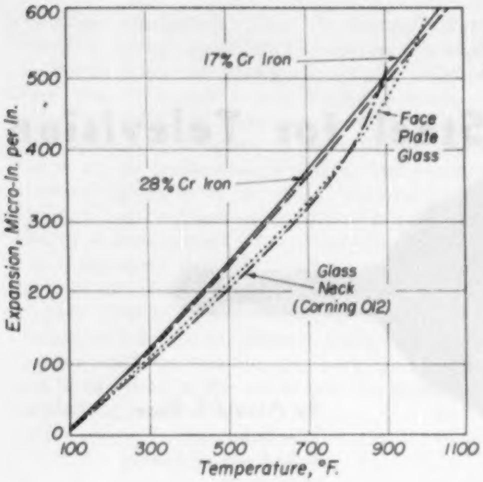

Fig. 1 — Thermal Expansion of Chromium Irons Is Nearly the Same as for the Two Glasses to Which They Are Sealed

Metal-to-Glass Sealing

On first consideration, the chromium-iron alloy containing 17% chromium would seem to have preference over the 28% alloy when the factors of cost and physical properties of each are compared. The greater ductility of the lower-chromium alloy makes for easier spinning, and its superior surface quality reduces the number of rejected cones. However, when attempts were first made to produce kinescopes with cones containing 17% chromium, successful glass-to-metal seals were impossible to make. Efforts to improve the situation through variations in sealing technique were futile, and it became obvious that the standard alloy containing 17% chromium was wholly unsuitable. In marked contrast to this inability to seal successfully, cones made with the 28% chromium-iron alloy sealed to glass with ease, and although the cost of the alloy was higher and its working qualities poorer, the 28% alloy became universally used for kinescopes.

Because the ability of any particular glass to seal to a metal depends largely on the thermal expansion match below the setting temperature of the glass, the striking differences in sealability noted between the two alloys cannot be explained fully by the small differential shown in Fig. 1 for the low-temperature range. Therefore, the effect of the glass sealing cycle on the structure of each alloy was studied up to 2200° F.

Importance of Austenite Transformation

The phase relationships in the iron-chromium-carbon alloy system have been the subject of thorough investigation. The commercial alloys under consideration generally contain about 0.30% nickel and 0.15% nitrogen, which extend the gamma loop to higher chromium concentrations. For instance, a typical 17% chromium iron containing 0.12% carbon, 0.15% nitrogen, and 0.30% nickel, when air cooled from 2200° F., will undergo partial transformation to martensite. By comparison, the alloy containing 28% chromium with similar amounts of minor ingredients is stable, being ferritic at all temperatures below the melting point.

The presence or absence of transformation in the chromium-iron alloys will have a decided effect on their thermal expansion and contraction and hence on their glass-sealing characteristics.

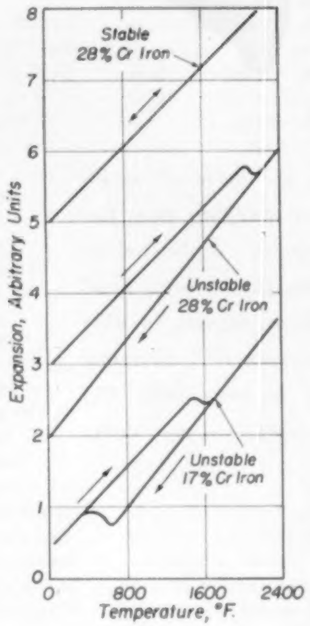

Fig. 2 — Expansion Through the Transformation Range

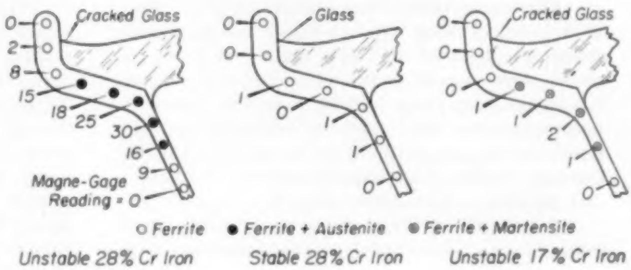

Fig. 3 — Cross Sections of Glass-Metal Junction at the Area Where Sealing Temperatures Are Maximum

For example, as shown in the bottom curve of Fig. 2, the 17% alloy will expand at a uniform rate from room temperature to about 1500° F., where austenite forms with a decrease in volume (and length). As austenite has greater expansivity than ferrite, the expansion curve rises with an increased slope to 2200° F., the temperature at which the glass is sealed to the metal. When the alloy is cooled from 2200° F., the reverse transformation to ferrite (or martensite) does not generally occur until a temperature of about 600° F. is reached. Below this temperature, the alloy expands during cooling until the transformation is complete and then contracts at the rate of the original ferritic alloy. The effect of these changes in expansivity on any glass which may be sealed to the alloy is disastrous, because the glass is brittle in the temperature range below 600° F. When a seal is cooled through this range, the glass follows its normally smooth contraction curve, which is entirely incompatible with the sudden change in the alloy from contraction to expansion. As a result of this incompatibility, tensile stresses are induced which cause the glass to fail (Fig. 4).

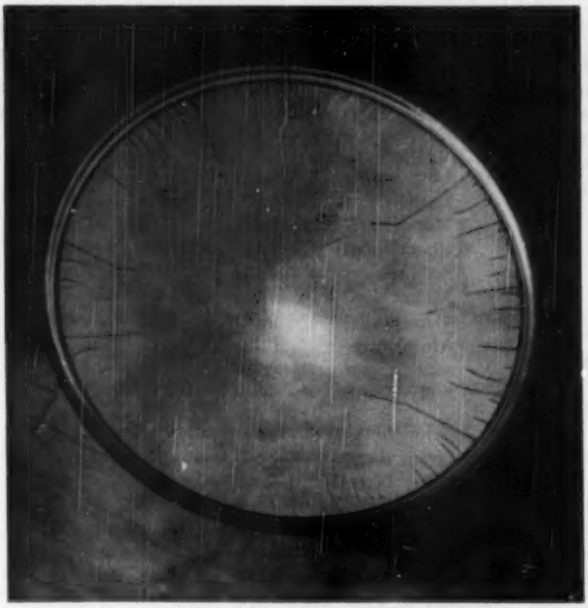

Fig. 4 — Cracks in the Glass Face of 16-In. Kinescope Having Metal Envelope Made From Unstabilized 17% Chromium Iron

By contrast, as shown in the top curve of Fig. 2, the 28% chromium alloy that undergoes no austenite transformation has a smooth and uninterrupted thermal-expansion curve throughout the heating and cooling cycle. Glass sealed to such an alloy will match the expansion through its solidification range and will not crack. Therefore, the 28% alloy can be used in kinescope manufacture.

Should the chromium content of the 28% alloy drop substantially or should the total of carbon, nitrogen, and nickel become too high, the alloy will transform partially on heating but not on cooling, as shown in the middle curve of Fig. 2.

Coefficient of Expansion

Typical numerical values for expansion coefficient on cooling from 930 to 85° F. are 6.1 micro-in. per in. per °F. for the stable 28% chromium-iron alloy, and up to 7.0, depending on the amount of austenite formed, in the unstable 28% steel. The latter alloy is obviously not so well suited for sealing to a glass with an expansion coefficient of 5.7 as is the austenite-free, lower-expansion alloy. However, in specifying the alloy for production use, allowance was made for the appearance of a small amount of austenite, and the top acceptable limit for the expansion coefficient is 6.3 micro-in. per in. per °F.

Magne-Gage Measurements

An interesting method of charting the course of these transformations by means of a "Magne-Gage" was suggested by T. V. Simpkinson and M. J. Lavigne in *Metal Progress* for February 1949. This instrument, which gives a quantitative reading directly proportional to the residual magnetism of the specimen being tested, can be used to detect the presence of small amounts of the nonmagnetic austenite. The results of a series of Magne-Gage readings taken on a 28% chromium iron showed that the formation of austenite is a maximum at 2155° F., a fact which may be confirmed by microscopic examination and estimation of the percentage of austenite in quenched specimens. The stability of this phase was similarly investigated by means of both Magne-Gage and microscope. No reverse (gamma → alpha) transformation took place on cooling to the temperature of liquid air (−300° F.) or on holding the alloy for 48 hr. at 660° F.

Transformations in the 17% chromium-iron alloys may also be verified with the Magne-Gage.

The magnetic properties of the 17% alloy remain essentially constant both before and after heating to 2200° F. That is, the austenite formed on heating reverts to magnetic ferrite on cooling. This condition is brought out clearly when the condition of the alloy in the rim of cones subjected to the actual sealing operations is explored with the Magne-Gage. In Fig. 3 are sketched the sectioned rims of cones made of a partially austenitic type of 28% chromium iron whose expansion was increased to such an extent that it caused the glass seal to crack, a 28% chromium iron to which glass was sealed successfully, and a standard (unstable) 17% chromium iron. The Magne-Gage readings indicate the extent to which the various alloys have transformed and, of course, are directly related to the microstructures of the steels and their tendencies to cause cracking of the glass. Cracks in a face plate sealed to standard 17% chromium iron are shown in Fig. 4.

Transformation-Free Alloy of Decreased Chromium Content

As a result of the foregoing observations it might be concluded that a chromium-iron alloy may be used for glass sealing at temperatures around 2200° F. either when entirely free from transformation or when only such a slight amount of austenite forms that the expansion of the alloy is not increased to more than 6.3 micro-in. per in. per °F. through the range 85 to 930° F. Although at first glance this conclusion would seem to eliminate the use of any chromium-iron alloy with less than about 28% chromium, further investigation pointed to a possible means of obtaining a less costly low-chromium alloy that would fulfill the stated requirements.

It was established by F. M. Becket and Russell Franks in 1934 that the addition of small amounts of titanium and columbium will diminish the air hardening characteristics of steels of various chromium contents. Titanium and columbium form insoluble carbides and stabilize ferrite. The thermal expansion curves for these alloys are, therefore, free from transformations which would disintegrate a metal-to-glass seal during the heating and cooling cycle. Since this type of expansion characteristic is precisely that sought for in glass sealing, the utilization of a chromium-iron alloy containing less than 28% chromium becomes feasible.

In addition to titanium and columbium, other elements have the desirable "ferrite-promoting" effect — for instance, silicon, aluminum, tantalum, molybdenum, tungsten, vanadium and zirconium close the gamma loop.

Modified Compositions

Final choice of chromium content for a stable alloy was motivated by the fact that the 17% chromium iron holds an optimum position with respect to cost, corrosion resistance, heat resistance, thermal expansion and workability. Experimental 17% chromium alloys were made with varying amounts of aluminum, columbium, molybdenum, titanium, vanadium, tungsten and tantalum. It was soon evident that these experimental alloys, when properly prepared, were ideally suited for glass sealing. Typical compositions of three modified alloys commercially available are:

	A	B	C
Chromium	18.5%	17.1%	18.1%
Carbon	0.08	0.06	0.08
Manganese	0.49	0.42	0.51
Phosphorus	0.02	0.02	0.02
Sulphur	0.01	0.006	0.008
Nickel	0.20	0.34	—
Titanium	0.62	0.68	0.35
Aluminum	0.11	—	—
Silicon	0.29	0.84	—
Molybdenum	—	—	0.9

The thermal expansion curve taken when one of these alloys is cooled from this temperature does not have the discontinuity associated with a transformation and is similar to the curve for stable 28% chromium iron shown in Fig. 2. Depending on the amounts of modifying elements added, the coefficient of thermal expansion of the stabilized 17% chromium alloy varies between 6.17 and 6.28 micro-in. per in. through the range 85 to 930° F. While these values for expansion are slightly higher than those normally obtained for the 28% chromium iron, this increased disparity with the expansion of the glasses used is only a minor consideration in making glass-to-metal seals.

The validity of the data obtained on the small experimental lots of the stabilized 17% chromium-iron alloys was established when large quantities of cones spun from this material were used in large-scale production of kinescopes. In these kinescopes the glass sealed successfully, and in every way the alloy proved a satisfactory equivalent of the 28% chromium alloy. Thereupon, direct introduction of the modified 17% chromium-iron alloy into the production line was accomplished without any serious dislocation, requiring no change in glass components or sealing techniques. Production of kinescopes with this newly developed alloy is now standardized, and a considerable saving in cost has resulted.

Modern Heat Treating

III—Interrupted Quenching

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Several items of heat treating lore have proved to be false when scientifically investigated. One was that the faster the quench the harder the steel — whereas in truth the steel's carbon content is the ruling factor. Another is that a cold quenching bath is necessary for adequate hardening, yet agitated molten salt has high cooling power. A third is that annealing requires very long times and slow coolings, yet cyclic annealing violates both rules-of-thumb. The authors show how modern salt baths and furnaces fit into these heat treating practices of 1950.

ADAPTABILITY of salt baths to handle various commercial heating assignments, formerly done in furnaces of various designs, has been expounded in two articles in *Metal Progress*, the second one (April 1950, p. 498) devoting itself to common heat treatments such as neutral hardening, carburizing, and cyaniding. The present article will devote itself to an outline of preferred methods of performing the more modern treatments of austempering, martempering and cyclic annealing, and end with a few remarks on solution treatment for age hardenable alloys.

Interrupted quenching treatments are based on the rapid cooling of the work to a selected temperature by quenching in hot salt. Its effectiveness depends on one of the properties of molten salt not widely recognized until fairly recently — namely, its cooling power at temperatures above 350° F.

The upper right set of curves in Fig. 9* shows cooling curves taken at the center of a 3.54-in. bar quenched from 1575° F. to produce structures with hardness of Rockwell C-57 to 60 when specimens are quenched in brine, water, oil and molten salt, respectively. (Since time-temperature transformation data are usually plotted to semilog coordinates, these curves for salt at 350° F., oil at 120° F. and water or brine at 50 to 60° F. are so plotted for ready comparison with S-curve data.) In each experiment, the quenching liquid was pumped through jets that produce a vigorous flow against and past the surface of the steel being cooled.

Examination of these cooling curves indicates that the cooling in the critical range between 1380 and about 700° F. is at a higher rate in a modern isothermal salt quench bath, properly agitated, than in hot oil. Thus, the center of this bar cooled from 1380 to 700° F. in 104 sec. in the hot salt, and in 176 sec. in the oil.

The lower left pair of curves presents further information on cooling in molten salt only, using the same 3.54-in. section, but measuring the temperature ¼ in. below the surface. It will be observed that the cooling rate of the bath is high only when adequately agitated. Thus, the time of cooling from 1380 to 700° F. is 90 sec. in agitated salt and 270 sec. (three times as long) in a still bath. The layer of hot salt close to the hot steel surface must be constantly replaced by fresh quench liquid. Furthermore, it should be realized that an isothermal quench bath is not a draw bath converted to hot salt quenching by the mere addition of a motor-driven propeller. It is a device

*Figure numbers are continuous with those in the preceding installment.

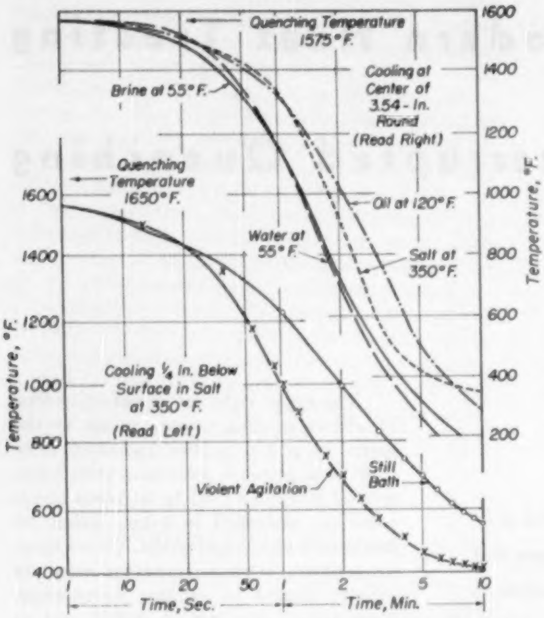


Fig. 9 — Cooling Curves at Center of 3.54-In. Round When Quenched in Various Mediums, and ¼ In. Below Surface When Quenched in Still and Agitated Salt at 350° F.

designed to extract heat rapidly from metal being quenched while at the same time dissipating this heat so rapidly that the bath is kept within 5° F. of the desired temperature. Such a quench furnace embodies the following important features:

1. The exterior of the pot and the air chamber surrounding it are designed as a heat exchanger to extract heat from the quenching salt by using a large volume of air.

2. One or more motor-driven submerged hot salt pumps are installed to propel the salt through nozzles against the charge being quenched, thus cooling heavy sections at maximum rates.

3. A salt-extracting apparatus of simple construction to remove drag-out contamination, that is, the high-temperature salt from the heating bath that is precipitated in the low-temperature quench bath. Otherwise, the chloride salt dragged over on the work from the austenitizing bath cakes up the sides and bottom of the quench pot, or floats in the molten bath, and would have to be removed manually. Moreover, an excessive accumulation of chlorides in the quench bath seriously affects its quenching power, as was discussed by A. M. White in his recent article in *Metal Progress*, "Variations in the Quenching Power of Salt Baths", December 1949.

A modern isothermal quench bath embodying all of these requisites is shown in Fig. 11.

Interrupted Quenching

The three major types of interrupted quenching processes in use today are indicated in the simplified diagrams below (Fig. 10):

1. Cyclic annealing, which produces a soft and easily controlled structure with a very short time cycle (at top of Fig. 10). It requires the highest temperature in the quench. (This should not be confused with "process annealing" at subcritical tempera-

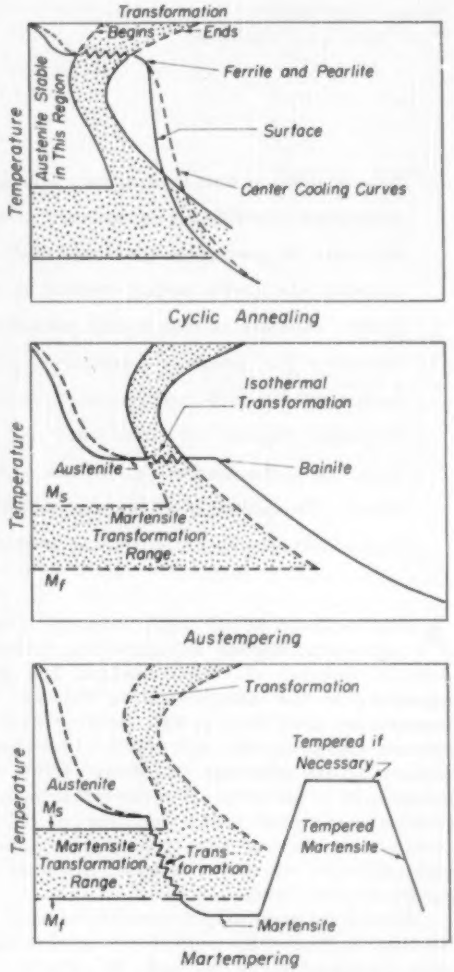


Fig. 10 — Diagrams Representing Time-Temperature Relations for Cyclic Annealing, Austempering and Martempering

tures, for which salt baths are also well adapted, as noted on p. 498 of *Metal Progress* for April.)

2. Austempering, which provides for medium hardness combined with ductility and toughness and good control of distortion (center of Fig. 10). It requires medium temperatures in the bath.

3. Martempering, which provides high hardness equal to oil quenching with greatly reduced distortion and practically no residual stresses in the hardened piece (at bottom of Fig. 10). It requires lowest temperatures in the quenching bath.

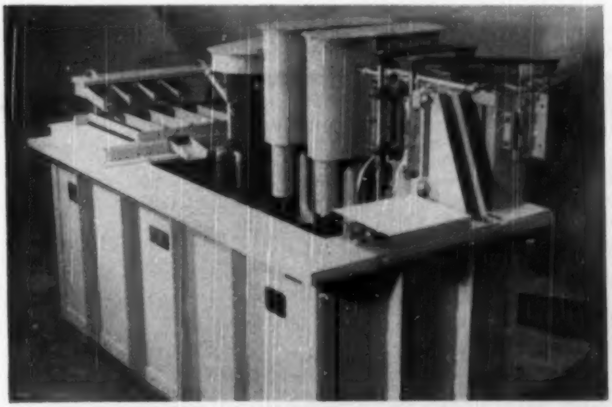
The equipment required calls, first, for a high-temperature furnace to put the work in an austenitic condition. This usually is a neutral salt bath furnace, but can be of any other type. Secondly, a quench furnace must invariably be provided with adequate means, automatically controlled, for keeping the bath at the correct temperature, irrespective of normal variations in the rate the hot steel is received. Agitating devices such as a pump or propellers are also necessary. The effect of adequate agitation cannot be overemphasized and the success or failure of the entire set-up depends upon it. Thirdly, a draw or stress relief furnace is sometimes required to temper the steel and to give the desired final hardness.

All three furnaces are generally salt baths. The quenching furnace is, of necessity, a salt bath and the work must be fixtured correctly for its introduction into this unit. Obviously, there will be no refixturing required if all furnaces in the series are salt baths. In that event, handling is greatly simplified.

Cyclic Annealing — The data made available over a decade ago by Peter Payson and others show that the S-curves indicate how steel can be annealed by transformation at a constant subcritical temperature in a comparatively short time. This process is called cyclic annealing. The steel is heated first to the austenitizing temperature (approximately 1500° F.) and then quenched in another bath operating in the range of 1100 to 1300° F. where it remains for the time indicated by the S-curve for that particular steel to complete transformation. The austenite transforms directly to the desired soft structure of ferrite and pearlite. Then the work can be cooled in air or water as rapidly as possible. Depending on the analysis of the steel, the total cyclic annealing operation requires from 30 min. to a few hours. The process is quite different from conventional furnace annealing requiring extremely slow cooling rates and cycles ranging from 5 to 24 hr. Large and successful installations utilizing the salt bath for cyclic annealing of cast-iron cylinder sleeves and piston rings, as well as wrought steel products, indicate a widespread acceptance of this revolutionary change in annealing practice.

Several forging manufacturers have already adopted the cyclic annealing process in a rather novel manner by utilizing the residual heat as the forging comes from the press or hammer. The hot forgings, still above the upper critical temperature, are quenched in an agitated salt bath operating at the subcritical temperature of the particular steel — 1150 to 1250° F. In a very short time the forgings are transformed to the desired pearlitic structure, after which they are given a water quench which removes all scale. Cleaning operations such as pickling or blasting can be eliminated and the forgings are ready for machining in an hour after they leave the press. The savings thus made possible by eliminating the reheat for anneal, pickling and sand blasting can be very substantial, in addition to which there is a clear indication that economies are made in the machining operations on cyclic annealed forgings because of the better grain structure.

Fig. 11 — Isothermal Quench Furnace Equipped With Submerged Pumps and Quench Heads, a Separating Chamber to Extract Salts Carried Over From Austenitizing Bath



Austempering is used for small or thin parts where hardness requirements fall between C-35 and 50, and where toughness or ability to bend without breaking after hardening is a requirement. Such parts as shoe shanks, typewriter parts, sewing machine parts, automobile bumpers, open-ended and socket wrenches, pliers, lawn mower blades and springs, are commonly austempered. The steel is generally one of the inexpensive

carbon steels of the S.A.E. 1000 series, although alloy steels are occasionally used.

Martempering, on the other hand, is usually performed on alloy steel, carburized steel, or high-carbon toolsteels, and greater sections can be treated successfully. Ball bearing races are a popular application; typically S.A.E. 52100 is used, and sections as great as 1¼ in. are now martempered. Likewise, many types of tools are martempered as well as gages and accurately finished parts carrying high stress or needing high hardness. The greatest advantage of the process lies in the control of distortion. Final grinding of heat treated parts is an expensive operation and the saving in even a moderate reduction of the finish grind can easily be greater than the total cost of heat treating. This idea was adequately expounded last month in *Metal Progress* in Messrs. Widrig and Groves' article on "Martempering of Automotive Gears and Shafts".

One of the most promising fields for martempering is the one which combines it with carburizing. For instance, an enormous quantity of gears are carburized and hardened which must then be finished by grinding or lapping to extremely close tolerances. A very substantial saving can be secured by a martempering quench direct from the carburizing bath.

Solution Heat Treatment

Salt bath furnaces are the preferred tool for heating alloys which are susceptible to age hardening. Their function is exactly the same as the austenitizing furnace in the steel treating set-ups just described — namely, to place all the constituents of the alloy into a homogeneous solid solution. After quenching to retain the solid solution, the alloy is warmed (tempered or aged) and enough insoluble constituents precipitate in disperse submicroscopic particles to harden and strengthen the metal. Several hundred very large units were put in this service during the war.

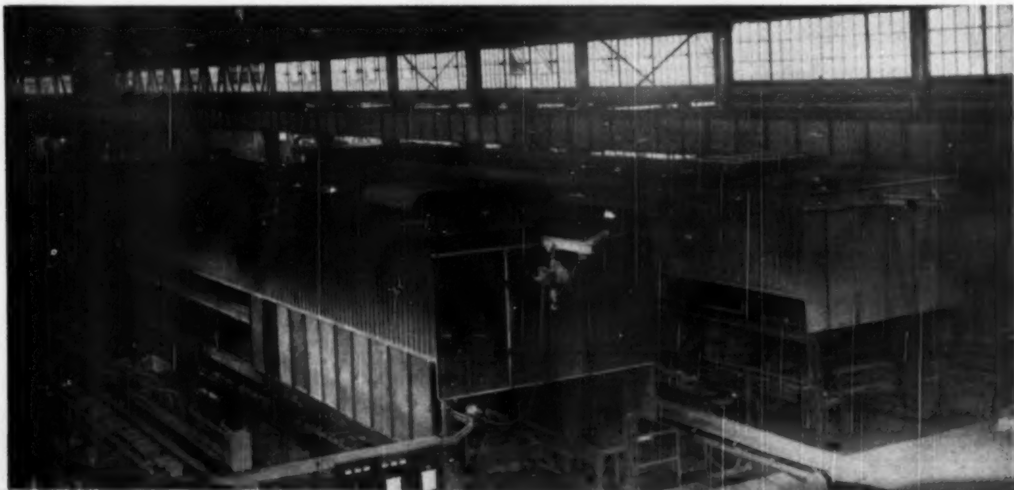
This treatment is applied commercially, to nonferrous alloys — principally of aluminum and copper. Copper-beryllium and copper-chromium alloys are being treated in large salt bath furnaces, some of which have connected loads of several hundred kilowatts.

The complete surface protection, the high rate of heating, the accurate temperature control are the major advantages offered by salt baths. In addition, however, the adaptability of the salt bath furnace is important; it is unnecessary to unload and quench an entire batch at one time; individual pieces are readily handled and the more rapid and efficient quenching which this permits is a valuable asset. It should be pointed out, however, that the salt bath furnace is most readily adaptable to those applications where a constant furnace temperature is satisfactory. Due to the great volume of salt it contains, important variations of temperatures either up or down cannot be endured without serious loss of time and increase in operating costs.

Conclusion

In this series of articles we have briefly described the major applications for which the modern electric salt bath has found widespread use. Other applications of considerable importance have not been mentioned, such as its use for process annealing, brazing, for surface cleaning, and for bluing. Enough has been said, however, to indicate that the salt bath furnace has attained a position where it merits consideration with older established heat treating processes. It is not a cure-all, but in many instances its inherent characteristics will produce unique results and economies.

Fig. 12 — Two Mechanized Continuous Lines for Austempering Bumpers, Finish Ground Before Heat Treating



Deep and Tapered Stampings Without Wrinkles

By R. Burt Schulze
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Here is a new solution for the problem of making deep stampings in moderate numbers, true to shape, and with inexpensive tools. Tooling costs are usually too high with accurate male and female dies. Form blocks using rubber pads for female die work well for bending, simple stretching, or a combination of the two. However, wrinkles are likely if the metal must be shrunk — a disadvantage corrected in this new process by confining the rubber pads on all sides with fairly high pressure varied correctly during the entire forming stroke.

WHEN the manufacturing research and development group was reorganized by The Glenn L. Martin Co., it became the center of all studies and projects aimed at improving production methods. These methods, in many instances, are quite special to the manufacture of airframes. For example, it is not unusual to find over 40,000 parts on a 32,000-lb. airframe, not including standard parts like rivets and couplings. If we have a contract for one airplane at a very low production rate, and another contract for a second airplane at a high production rate, all parts, most of which are sheet metal, must be manufactured on the same facilities and machine tools. Even at best, the number of parts to be made of a single size and shape is small by mass production standards; automobile body factories can put an enormous amount of time in perfecting a set of dies so a front fender comes out clean and smooth. Airframe builders have had to be content with much bench work to iron out irregularities and bring the stampings to specification limits. We happen to call this group our "tap-tap" department. Much of their work was caused by wrinkles in deep drawn parts. One obvious aim of manufacturing research was to eliminate the wrinkles, and therewith the "tap-tap" department!

It is well-known that the aircraft industry uses the Guerin process for a multitude of sheet metal parts. Essentially this is different from mass-production dies of steel (male and female mating parts, with or without pressure pads in double-action presses) in that the Guerin process, on the other hand, is essentially a process in which rubber blankets are used as a substitute for the female portion, but it has no good substitute for the pressure pads. This process of forming with a semifluid medium definitely offers an opportunity to save much money in tool cost on short production runs.

Figure 1 is a schematic section through the equipment and tooling utilized in the Guerin rubber hydraulic press method of forming stampings. This illustration shows the retainer loaded with rubber and mounted on the upper ram of the press. It also shows the lower platen mounted on the bed of the press, supporting a single form block and a partially formed blank on the form block. It works very well when the stamping operation involves either a straight bend in the metal, stretching of metal, or a combination of the two, since there is no tendency to wrinkle. However, the inability of the Guerin process to shrink metal is a definite cause of wrinkling. First, the pressures employed have not been high enough to solidify the rubber to sufficient local stiffness to prevent wrinkles. A simple increase in pressure would not

solve the problem, however, since wrinkles can begin to form before any pressure is built up in the rubber to prevent their formation. The small illustration at the right shows a wrinkle in metal and how pressure tending to maintain the wrinkle (by preventing sidewise movement as well as a certain amount of upsetting) is large in proportion to the pressure tending to press out that same wrinkle.

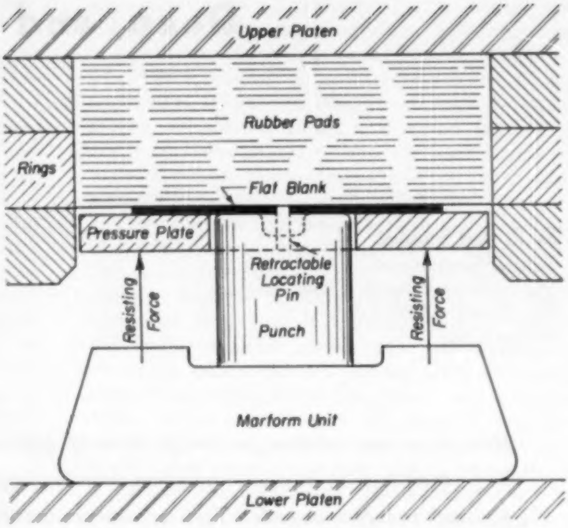


Fig. 2 — Tooling in Single-Acting Hydraulic Press for Making a Flanged Cup. Position shown is after blank has been placed on top of punch and pressure plate, and upper platen lowered to where rubber blankets are in contact with work. The beginning of the forming stroke

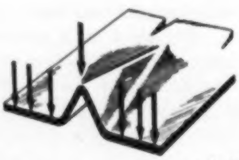
Our experimentation in the manufacturing research and development group, therefore, was to devise some scheme that would have the advantages of a semifluid die (Guerin process) *plus* the ability to control the amount of pressure progressively and thus prevent the formation of wrinkles. It turned out that when this objective was achieved we also gained the equivalent of pressure pads in double-acting mechanical presses.

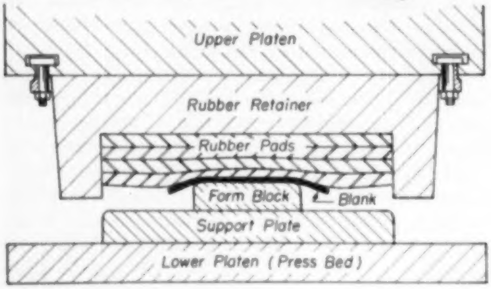
Figure 2 shows that, in this process* (called "Marform"), the rubber pads or female die, contained in retainers attached to the upper platen, are prevented from moving sidewise and downward freely as the press closes. A steel pressure plate, cut to fit the retainers and to slip freely over the punch (or punches), provides this bottom support. As the upper platen descends, the pressure plate also retracts, being supported continually by a hydraulic mechanism in the Marform unit placed on the bed of the press. By cam-operated valves, driven by the press movement, the pressure imposed on the pressure plate can be varied in any desired manner. It can start low and be increased at any rate; it can start high and be decreased; in fact, an infinite number of programs is possible.

Comparison of Fig. 3 with Fig. 2 shows that this arrangement not only holds the flange at all portions of the stroke, and thus controls the shrinking area from tangent point to outer edge of the blank, but also puts a lateral pressure during the forming operation which is a direct result of the applied forming pressure. This lateral pressure has the effect of locking the metal already formed to the male portion of the tool. This prevents an accumulation of strain at the punch radius, and thereby causes the strain to be distributed very uniformly over the complete surface of the piece to be formed. Most steel die formed parts which fail, fail when the top pops out of the part, breaking along the line of the punch radius.

Prevention of concentration of strain at the punch radius not only enables the part to be formed deeper but also causes the part to be more satisfactory in certain applications where uniform thickness is important.

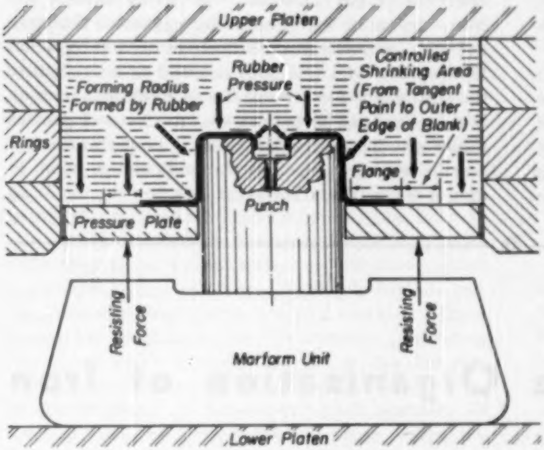
Fig. 1 — Press Forming With Rubber Pads (Guerin Process). Small view shows that, once a wrinkle occurs, the rubber pressure tends to maintain it rather than iron it out flat





*Editor's Note — A press release from the company says that this development evolved principally through the efforts of four men: R. B. Schulze, supervisor of research and development; H. Hessler, tool engineer; C. O. Davison, hydraulics engineer; and Mahlon Winter, machine designer.

Fig. 3 — *End of Stroke. As the upper platen descends, the pressure plate also retracts — however, it exerts correct pressure through hydraulic action of the Marform unit*



plates on the same machine). The pressure requirements and depth of stroke must of course be equal, however, for all parts formed at the same time.

Ability to form metal may be expressed in radius of cup that can be drawn in relation to the radius of the flat blank. On this convention, steel dies can readily reduce aluminum 40% (50% if extra care is taken). Normal reduction by Marform is 57%; 70% has been attained.

Depth of cup is another criterion. Steel dies should produce a cup as deep as its radius. Marform regularly makes cups 1.5 times the radius, and 2.4 times has been done.

Likewise the new process is good with very thin sheet. Our manufacturing experience extends to the limits 0.010 in. and 0.675 in. in aluminum, and 0.020 in. to 0.102 in. in A.I.S.I. 1010 steel, although we feel that these limits might readily be extended substantially if necessary.

There is another related advantage in the fact that the rubber locks the material against the punch. This arises from the phenomenon that very local elongations in metal can safely be higher than elongations over a relatively longer gage length. The rubber automatically causes the metal to be strained over a much shorter gage length by locking it just above the instantaneous point of forming and therefore provides the elongation available from the shorter gage length.

In the Marform process, therefore, tooling is no more difficult than in the Guerin process, other than that a pressure plate (ordinarily flame cut) must be provided.

This plate must be flat and smooth but the fit between it and the punch is unimportant except when forming very thin metal such as 0.010 or 0.020-in. stock. A thin "masonite" overlay on the steel plate will save the cost of grinding the surface for short runs.

The Guerin process has another big advantage over steel dies in that the set-up time is negligible; any arrangement of tools can be distributed around the lower platen. The Marform process again strikes an effective compromise. Here the set-up time is relatively small since the male and female portions of the tool do not have to be matched, and since more than one form block can be used in one pressure plate (or in separate pressure

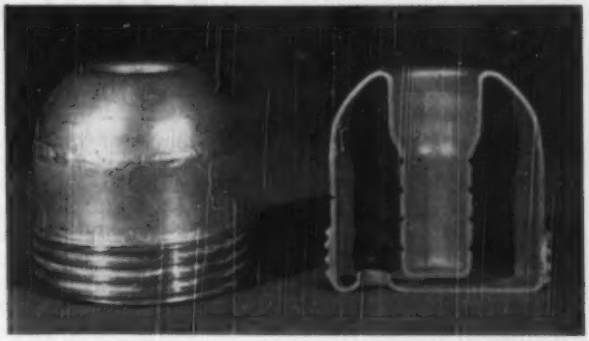


Fig. 4 — Cutaway View of the Upper Half of an Igniter Head — That Part Above the Weld Including the Cylindrical Portion Extending Down Into the Lower Shell. This was made by the Martin Marform process in five operations, instead of the nine required by more conventional methods

Finally, its ability to make tapered shapes is an added advantage, since any tapered shape tends to wrinkle, due to the distance between the punch and the pressure plates of the die at the start of the forming stroke. Nevertheless, tapered shapes are important to industry because they are attractive, because they will stack better, and because they save metal. The following examples will serve as a guide to the severity of taper which can be formed by the Marform process without wrinkles. Consider a 4-in. diameter on the top of the punch and with a taper outward toward the bottom of

the punch. On such a punch the gap could be ½ in. between punch and supporting pressure plate for forming 0.025-in. thick steel. This gap can be increased to ¾ in. if the gage is increased to 0.050 in. The gap can be $\frac{3}{16}$ in. with 0.025-in. aluminum, and ⅜ in. with 0.050-in. aluminum.

In conclusion it may be said that results so far have been most satisfactory. Representative parts that would require at least 15 min. bench work can now be made without any attention by the "tap-tap" department. The largest blank we have formed so far is about 28 x 31 in., but the only limitation in this respect is the size of the equipment available. Another possibility, as yet not well explored, is the forming and simultaneous shearing in any direction. So much interest has been shown in the process by engineers throughout the metallurgical industries generally, that Hydropress, Inc., has been licensed to manufacture the equipment for general use in hydraulic presses. We are inclined to believe that mechanical presses might also be used, if the press is powerful enough and if the jaw opening is sufficiently wide to mount an auxiliary Marform unit.

The Organization of Iron and Steel Research in Russia

The following statements on organization of ferrous metallurgical research in the U.S.S.R. are quoted from an article by G. Delbart in Revue de Metallurgie *for April 1949. This extract is followed by editorial remarks concerning the publication of Russian metallurgical papers. Beginning on p. 798 are printed extended abstracts of five recent articles from Russian technical journals. Of particular interest is the description of a magnetic method of determining the hardenability of steel (p. 816), a method which, properly calibrated, would seem to have several advantages over the widely used end quench test. Also abstracted are papers on multiple-arc welding of thin sheet metal (p. 808), effect of grain size on the high-temperature strength of austenitic alloys (p. 798), tests for forgeability (p. 838), and effect of alloying elements on the hardness of ferrite (p. 802).*

BEFORE 1914 scientific metallurgical research was carried on in the laboratories of advanced technical schools, the universities, large factories and large arsenals. Metallurgy was taught in the School of Mines of St. Petersburg, founded in 1773. The Polytechnic School of St. Petersburg had a program analogous to the French Polytechnic School. At the School for Roads and Bridges, founded in 1810, there was a center for testing materials. A large central testing laboratory was also started before 1914, and one of its branches was directed by the metallographic scholar, N. Belaiew. Other institutions such as the Upper Technical School, of which Dimitri Tchernoff (1839-1921) was a product, and the Polytechnic Institute of Lesnoye should not be forgotten. Scientific research in general and metallographic science in particular were in full swing by 1914.

After the war of 1914-18 and the civil war that followed, the Soviet government reorganized teaching and research and founded a considerable number of advanced technical schools and research institutes all over the U.S.S.R. At the present time the number of these institutions and large industrial laboratories is more than one thousand. The institutes can be separated into four groups: the

Academy of Sciences, advanced schools, institutes of (properly speaking) research, and laboratories of industrial research.

The Academy of Science boasts institutes which are among the best equipped in the world, notably an Iron Institute, in Moscow, with a branch in the Urals. Its budget is directly approved by the Council of Ministers and its president is one of the Council of Ministers of the U.S.S.R. The Government entrusts the Academy of Sciences with basic work most important to the national interest, and the Academy controls in principle all research undertaken in the U.S.S.R.

The Soviet universities generally do not concern themselves much with iron; however, some ten of the advanced technical schools include ferrous metallurgical instruction and research. These researches are financed by the ministry supporting the school or by an industrial group, but the general program must be submitted to the approval of the Ministry of Education which controls all schools, even those depending on other ministries.

Each ministry has its own institutes of research. The Iron Ministry has eight institutes. The main one is in Moscow; other well-equipped ones are at Sverdlosk in the Urals, at Stalinsk in western Siberia, and at Dniepropetrovsk. Researchers are allowed to use the results of their work to obtain university degrees. A thesis for the degree of "candidate" requires about two years of experimental work; a thesis for the doctorate of science about five years. Along with a university degree, particularly that of doctor of science, goes an appreciable increase in salary and other material advantages.

Most of the work undertaken is due to the initiative of the researchers, but in order to receive the necessary financial support they must furnish a detailed plan, state precisely the goal to be attained and promise completion of their project in a rather short time. When laboratory work is to be extended to industry, the researcher is usually given supervision and even the execution of factory tests, or experiments in the semi-industrial pilot plants attached to the institutes.

Soviet Metallurgical Publications

A RECENT Russian textbook ("Metallovedenie", by A. A. Bochvar) contains an appendix evaluating the metallurgical publications of various countries. The four principal Russian journals are given there as: *Stal* (Steel), *Tsvetnie Metally* (Nonferrous Metals), *Izvestiya Sektora Fizikikhimicheskova Analiza* (Bulletin of the Branch of Physico-Chemical Analysis), and *Zhurnal Teckhnicheskoi Fiziki* (Journal of Technical Physics). Only the last of these is received and abstracted regularly in the United States.

Papers of metallurgical interest are by no means limited to the four principal mediums. Seventeen Russian journals are annotated in the "A.S.M. Review of Metal Literature", and in 1948 the Review carried references to 425 Russian articles, of which 70% were in the following four categories:

Analysis and Testing	36%
Joining (chiefly arc welding)	15
Properties of Metals	11
Constitution of Alloys	8

This distribution of subjects should not be regarded as typical of metallurgical activity in the Soviet Union. It is more likely an indication of the type of literature considered exportable. Also, the preponderance of articles on mechanical and chemical testing is due chiefly to the large number of short articles appearing in one journal, *Zavodskaya Laboratoriya* (Factory Laboratory). Papers about foundry operations, for instance, are missing; and scant information is available on machining practice, although the annual production of machine tools in the U.S.S.R. has been reported as increasing from 55,000 units in 1939 to 1,300,000 planned for 1950.

Ten of the 17 Russian journals covered by the A.S.M. Review are issued by the Academy of Sciences of the U.S.S.R., which publishes a long list of *Bulletins*, *Journals* and *Reports*. One finds in the Academy publications a great variety of metallurgical information — all the way from electron density of alloys to such unacademic subjects as the heterogeneity of steel ingots and the preheating of fuel in a shaft furnace.

There is also another type of article which appears occasionally under the standardized title, "The Priority of Russian Science With Respect to Knowledge Concerning . . ." Regardless of the accuracy of any particular claim to priority, the Russian metallurgists *are* currently turning out some important research. American chemists have recognized the value of Russian chemical literature, as indicated by the fact that two Russian chemical journals are being republished here in English and sold on a subscription basis for $80 and $95 yearly. A similarly comprehensive project for translating and republishing metallurgical papers may or may not be feasible, but the American metallurgist should not blind himself to a vast and varied amount of research and development being carried on throughout Eurasia. Perusal of the five extended abstracts beginning on p. 798 of this issue will give the reader some indication of the type of research being reported.

The Core of Graphite Spherules in Nodular Cast Iron

By A. L. De Sy
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IN AN ACCOUNT of Belgian researches concerning nodular iron published in *American Foundryman* for June 1949, the present author considered the mechanism of formation of the graphite spherulites, and put forward the hypothesis that some compound of magnesium had a nucleating influence, once the suspended silica particles were completely eliminated. Likewise cerium or lithium compounds had the same effect as magnesium.

In recent work sponsored by Centre National Recherches Métallurgiques, a careful examination of well-prepared sections of nodular iron revealed a surprising number of nodules with a "core" in the center. Even supposing that this core is really a nucleus, the number shown in Fig. 1 is surprising, since only those spherulites cut by a nearly diametrical plane should show it.

Consequently, before discussing the nature of the supposed "core" it is obviously necessary to find out if there is really any other material present in the center of the spherulite. In other words, is there really a "core" or is it only the result of an optical effect?

We know indeed that graphite spherulites consist of crystallites growing outward from a center (nucleus). Generally each crystallite is so oriented that its basal planes are at right angles to the radii of the spheroid of which each spherulite can be considered to be composed. When the polished section lies above or below the center of the spherule, the crystallites in the middle of the exposed surface are so oriented that their basal planes lie parallel to the polished surface.

The important question is thus: "Is the 'core' we are looking at nothing else than this central zone or is it really a nucleus of nongraphitic material?"

To answer this important question, we had recourse to the electronic microscope, and for this study we are indebted to our friends and colleagues P. Coheur and L. Habraken at the University of Liège. Some of their results are shown in Fig. 2.

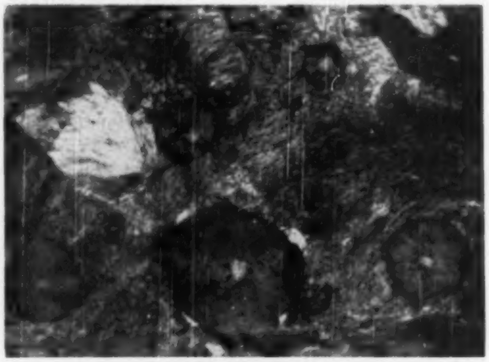

Fig. 1 — Graphite Spherulites With a Distinctly Light-Colored "Core" in Their Centers. ×500

There is evident a distinct core, geometrically shaped. Since the electronic microscope excludes optical effects, it may be accepted that a germ or nucleus actually exists.

One of the electronic micrographs did not show the nucleus, but a dark spot — apparently a hole wherefrom the core was drawn during polishing. It was of interest because it clearly showed the bladed nature of the graphite crystallites, and also an outer layer of secondary eutectoid graphite — the nodular iron sample having been completely ferritized by annealing.

Knowing, now, that there is a definite nucleus of some kind in the center of the graphite spherulites, it is next of importance to learn something about its nature.

Treatment of molten cast iron with magnesium brings about very complete deoxidation and desulphurization, with the formation and elimination of MgO and MgS. In well treated iron, wholly nodular, analysis of the solid metal gives (for example) 0.07% Mg and 0.007% S. It may thus be assumed that the MgS is really eliminated from the melt by rising to the surface slag and the residual magnesium in the solid is, for the most part, combined with other elements than sulphur, existing possibly as MgO, Mg_2C_3, MgC_2, or in a complex carbide of silicon and magnesium. In order to determine if the residual magnesium is to be found in the nucleus as a nucleating compound, we separated magnetically the graphite from the metallic matrix and submitted this graphite to spectrographic analysis. It was found that the graphite did contain a high proportion of magnesium — proportionally much more than the average content of the iron from which the graphite nodules were separated.

Similar analyses were made in mid-1949 by two foreign metallurgical laboratories, experienced in spectrographic analysis for magnesium. One confirmed exactly our results; the second also found magnesium in the separated graphite, but it did not appear clearly that the graphite contained much more than the average magnesium content of the iron.

More recently P. Coheur at the University of Liège analyzed spectrographically the graphite and other undissolved compounds from a wholly ferritic nodular iron sample, dissolved by the iodide method, and found important contents of magnesium and silicon.

Still another result may be mentioned:

In a heavy nodular iron casting (ferritic as cast) we found an average content of 0.066% Mg. This iron was hypereutectic and contained 3.50% carbon as graphite spherulites and 0.010% S. The upper portion of this casting, a layer about 1 in. deep, contained a three or four-fold segregation of graphite spherules. This portion analyzed 10 to 12% carbon as graphite spherulites, 0.21% Mg and 0.012% S.

It is of more than ordinary interest to note that the proportion of graphitic spherules to magnesium was substantially constant in both segregated top and unsegregated center of this casting. For example, in the bulk of the casting $3.50 \div 0.066 = 53$; in the segregated top layer $11 \div 0.21 = 52$.

From the above results it appears possible that crystallization of nodular iron is nucleated by a magnesium compound, and that the graphite spherulite results from the decomposition of a complex magnesium-silicon-carbide. Results communicated to the International Foundrymen's Congress at Amsterdam in August 1949 show that, in order to obtain wholly nodular iron with well-formed spherulites, all the carbon in excess of the solid solubility must be primarily precipitated, even if the melt is hypo-eutectic. Therefore it is believed that magnesium compounds act as nuclei, and that local concentrations high in silicon resulting from late additions do exist in the melt.

Fig. 2 — Electron Micrograph of Graphite Spherulite With a Distinct Nongraphitic Core. Magnifications 2000 and 7000 diameters, respectively

Toughness of Titanium

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IN the last two years much has been published on the mechanical properties of titanium and titanium alloys, but notched-bar impact data are still scarce. Because toughness is of importance in designing for a wide variety of applications, we have studied the effect of temperature on the impact strength of commercially pure titanium and one titanium alloy. In addition, true stress – true strain tests were made on commercially pure titanium to investigate its strain hardening.

For the impact tests, four lots of material were used, identified as follows:

Lot 1A — Reduced from $TiCl_4$ by magnesium, ground to powder, leached to remove impurities, pressed, sintered, sheath rolled to plate at 1650° F., and quenched. Analysis showed 0.3% Mg, 0.15% Fe, 0.15% O, 0.036% Ca and 0.005% Si.

Lot 1B — Same as Lot 1A, except not sintered.

Lot 2 — Reduced from $TiCl_4$ by magnesium, heated to volatilize impurities, arc melted in a water-cooled copper furnace, and forged at about 1700° F. to a bar ½ x ½ in. Analysis showed 0.11% Fe, 0.026% N, 0.025% C and traces of Al and Cr.

Lot 3 — Reduced from $TiCl_4$ by magnesium, heated to volatilize impurities, resistance melted in graphite for alloying, and forged to a bar ½ x ½ in. Analyzed 4.6% Cr, 3.1% Al, 0.49% C and 0.022% N.

Table I gives the room temperature tensile properties of the metals used for impact tests. Standard V-notch Charpy specimens were machined from each lot and tested at temperatures ranging from –320 to 1470° F. Results of these tests are plotted in Fig. 1. The difference in energy levels between the sintered metal (1A) and the unsintered (1B) was probably due to a difference in porosity. Metallographic inspection revealed that titanium 1B contained more voids than 1A, and any porosity directly behind the notch of the specimen could affect the energy values. This porosity and the colored oxide films which formed on the freshly broken surfaces precluded classification of the appearance of the fractures as brittle or ductile; the temperature of transition from tough to brittle failure was determined solely by the energy absorption values. For titanium 1A and 1B the transition temperature was about 925° F.; that is, despite their differing energy levels, the sintered and unsintered specimens showed no noticeable difference in transition temperature. The transition temperature of 925° F. means that the material will behave brittlely up to relatively high temperatures, and is accordingly unsuitable for many applications where toughness is required.

Although transverse specimens have an energy absorption 3 to 5 ft-lb. lower than the longitudinal specimens, the transition temperatures were about the same.

The titanium which had been melted (Lot 2 and material tested by Remington Arms Co., Inc.†) had a transition temperature about 800° F. below that for the titanium made from powder without melting (1A and 1B). Also, the transition from brittle to tough behavior was much steeper for the titanium that had been melted. This is not unexpected; transitions at low temperatures are usually steeper than those at high temperatures.

Table I — Room Temperature Tensile Properties

Lot No.	Tensile Strength	Yield Strength	Elongation in 2 In.
1A	75,000 psi.	50,000 psi.	20%
1B	80,000	50,000	7
2	85,000	60,000	16
3	203,000	190,000	5

Our test results on titanium 2 and the data published by Remington (Fig. 1) show appreciably less scatter than the data for 1A and 1B. This may be due to the more homogeneous nature of

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†"Technical Information on Titanium Metal", Remington Arms Co., Jan. 27, 1949.

melted metal compared with that produced by powder metallurgy.

Figure 2 is a curve of energy absorption versus temperature for the high-strength titanium alloy. There is little variation in energy values below 1200° F. but near 1200° F. the impact energy rises rapidly with increasing temperature. Room temperature hardness measurements before and after impact testing indicated that a permanent softening

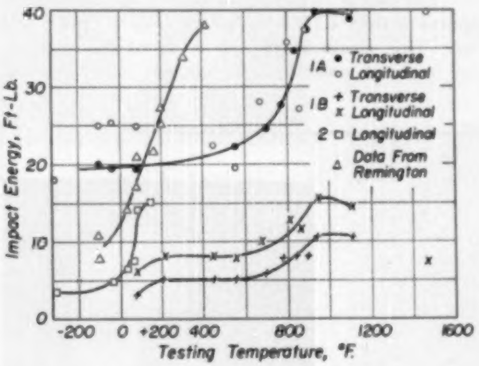


Fig. 1 — Impact Energy for Commercially Pure Titanium. Standard V-notch Charpy specimens

had occurred in bars tested above 1200° F. However, a dilatometric test showed no phase change in the alloy below 1650° F. Therefore, it is believed that the permanent softening was an overaging effect.

Despite the small number of specimens available from each lot the data indicate that a rather

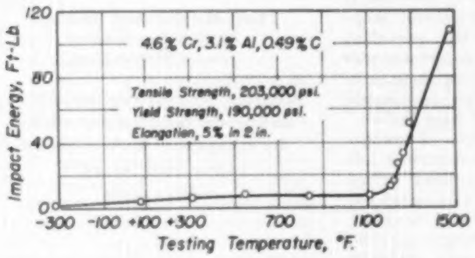


Fig. 2 — Impact Energy for High-Strength Titanium Alloy. Standard V-notch Charpy specimens

small increase in temperature causes the titanium to undergo a transition from low to high energy absorption. Although the appearance of the fractured surfaces was difficult to classify as either ductile or brittle, the sides of the Charpy specimens showed evidence of appreciable flow at the high energy level and very little flow at the low energy level.

Strain Hardening Test — The results of true stress – true strain measurements on two 0.357-in.

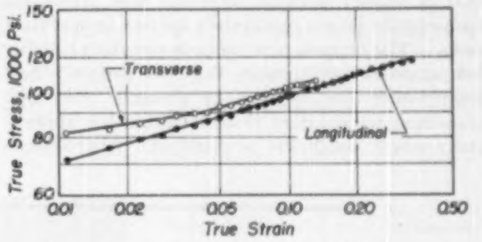


Fig. 3 — True Stress Versus True Strain for Commercially Pure Titanium (Lot 1A)

diameter tensile bars machined from titanium 1A are shown in Fig. 3. Simultaneous measurements of load and diameter were made on each bar and from these measurements the true stress [load/instantaneous area] and the true strain [ln (original area/instantaneous area)] were calculated. A strain rate of approximately 0.0008 per sec. was used.

When true stresses, s, and true strains, e, are plotted on a logarithmic scale they fall on straight lines, the equations of which are of the form $s = ke^m$, where k is a proportionality constant and m is the strain hardening exponent or slope of the line. The data for the longitudinal specimen fall substantially on one straight line of slope $m = 0.14$. The measurements of the transverse bar, in contrast with those of the longitudinal bar, form two distinct straight lines of different slopes which intersect at a strain of 0.045. The first line has a slope of 0.065, but the second line has the same slope as that found for the longitudinal specimen, 0.14. Similar results showing two distinct lines have been obtained by J. H. Hollomon (*Transactions*, A.I.M.E., Vol. 162, 1945, p. 268) for steel and by R. S. French and W. R. Hibbard (*Transactions*, A.I.M.E., Vol. 188, 1950, p. 53) for copper alloys.

The value of strain hardening exponent ($m = 0.14$) for titanium is low in comparison with that for copper alloys ($m = 0.4$ to 0.6) and about the same as that for most steels ($m = 0.1$ to 0.2). However, judging from the creep curves reported by H. Adenstedt in *Metal Progress* for December 1949, it appears that the plastic behavior of titanium is sensitive to strain rate, even at room

temperature, and our value of $m = 0.14$ may not be applicable at strain rates much different from 0.0008 per sec.

Conclusions — The commercially pure titanium and its alloy tested by notched-bar impact tests exhibit transitions from brittle to tough behavior, of the type found in steel and certain other metals; that is, impact strength increases with increasing temperature over a moderately narrow temperature range. The temperature range is usually at higher temperatures for titanium than for properly heat treated alloy steel of the same strength. This high transition temperature is undesirable for applications where toughness is required. Approximate transition temperatures (V-notch Charpy test) for the titanium tested are as follows:

Titanium produced by powder metallurgy, and rolled	925° F.
Titanium melted, cast and forged	100
Titanium-chromium-aluminum alloy	1250

The production of titanium and titanium alloys is still in a very early stage, and considerable improvement in toughness can be expected as further development takes place.

The strain hardening exponent of titanium is approximately 0.14, at a strain rate of 0.0008 per sec. This strain hardening is about the same as for steel but lower than for copper.

Distinguished Metallurgists

Five of the 75 recipients of the Society's "Distinguished Service Award for Contributions to Progress in Alloy Steel"

Robert B. Schenck

Chief Metallurgical Engineer
Buick Motor Division
General Motors Corp.

Citation "for devising inspection and production methods whereby manganese steels could be widely used for automotive parts"

A GRADUATE of Lehigh in 1909, BOB SCHENCK entered the steel industry at the Homestead Works of the Carnegie Steel Co. It was here that he first became interested in the possibilities of pearlitic manganese steel. In his own words:

"While working as a foreman in the armor plate department at Homestead in 1914, I ran across a sample of 0.35 carbon, 1.50 manganese steel which showed remarkably good tensile properties in the heat treated condition. These results indicated that manganese might be used in place of chromium or nickel.

"Further work was greatly hampered by difficulty in obtaining additional samples from other heats to verify the first results. Anything in the range of 0.20 to 0.50 carbon and 1.25 to 2.00 manganese was almost nonexistent. Laboratory melting furnaces were not readily available at that time for making experimental lots and, if they had been, most of us would have hesitated to predict openhearth properties from laboratory melts. About the only material to be found was occasional scrap from some heat that had been rejected because of its high manganese content.

"Another obstacle in the development work was the general skepticism encountered, the prevalent attitude being that if manganese was any good as an alloying element in the pearlitic steels, this fact would have been discovered long before."

Such was the status of manganese steel at the time SCHENCK left Homestead. After a brief period (1914-1915) as metallurgist for Erie Forge Co., he went to Flint, Mich., as chief metallurgist for General Motors' axle division. In 1917, SCHENCK became chief metallurgical engineer for Buick Motor Div., a position he has held ever since, except for one year (1933) with Pittsburgh Crucible Steel Co.

At Buick, SCHENCK resumed his interest in pearlitic manganese steels. The first full-size heat (1.58% manganese, 0.35% carbon) was made in 1922 and passed all required tests for axle shafts, for which Buick was then using S.A.E. 3135. On the basis of these tests, manganese steel was adopted for Buick axle shafts, and later for steering knuckles, steering arms, transmission gears and other high-duty parts. Finally, these steels were standardized as the S.A.E. 1300 series.

Howard J. Stagg

Sanderson-Halcomb Works
Crucible Steel Co. of America
Syracuse, N. Y.

Citation: "Lifelong proponent of intelligent use of alloy steel, who influenced practices in many consuming industries"

HARDLY a chapter of the American Society for Metals but has heard HOWARD STAGG'S salty discourses on how to use good steel to best advantage. Indeed there is extant a reprint of his talk before the Steel Treating Research Club of Detroit — the earliest predecessor of the . He is equally welcome at meetings of the American Society of Tool Engineers and similar groups of men. He may be billed to speak on many subjects, but the fundamental credo is:

1. Make good steel first.
2. Cut down rejections.
3. Increase yield.
4. Make as much good steel as you can, consistent with the above.

As he says, "That has been my life, and it has been fun!"

A young graduate in chemistry from Columbia, Class of 1909, STAGG was hired by the late, great JOHN A. MATHEWS as assistant in the metallurgical department of Halcomb steel plant. There he found five 4-hole, 24-pot crucible furnaces, a 20-ton tilting openhearth, and a 3-ton electric furnace (the first in America). Better, he found (along with Dr. MATHEWS, the operating manager) MARK LOTHROP — later Timken's general manager — and DICK READ, electric metal maker *par excellence*. What more could a young lad want as an outlet for enthusiasm and inquisitiveness?

STAGG is the only survivor of this group which was producing electric alloy steels for the then rapidly expanding automobile industry. Nickel steel (3½% nickel), chromium-vanadium steels and chromium-nickel steels appear on the Halcomb melting record in 1909, tungsten magnet steel in 1911, Krupp chromium-nickel in 1914, chromium magnet in 1915, and high chromium stainless in 1919. For several years he was a member of the Society of Automotive Engineers' committee in charge of alloy steel specifications.

As time went on, HOWARD STAGG was promoted to chief metallurgist, transferred to operations as assistant manager, then to sales, then to metallurgical sales until now he enjoys a position in which his duties are not specific nor defined but he does pretty much what needs to be done at the moment. It is a sure bet that much of that relates to the intelligent use of alloy steel in the consuming industries.

Herbert W. Graham

Vice-President and Director
of Technology
Jones & Laughlin Steel Corp.
Pittsburgh

Citation "for perfecting manganese steels used widely for oil field equipment, armor and other heat treated parts"

AS RECENTLY as 1920, steel containing from 1 to 3% manganese was believed to be hard, brittle and commercially useless. Today, these manganese steels are used successfully in a wide variety of applications. Much of the metallurgical development that brought about this change was directed by HERBERT W. GRAHAM in the laboratories of Jones & Laughlin Steel Corp.

A graduate of Lehigh in electrometallurgy, HERB GRAHAM has been employed continuously by J. & L. since 1914. His first exploratory work on manganese steel was aimed at application in heavy-duty bolts. Later, in 1925, he suggested a high-sulphur steel with manganese between 1 and 2% for openhearth screw stock to be used in making piston pins. The machinability of this grade was so good that its use has expanded steadily; much of the anti-aircraft ammunition used by our armed forces in the second World War was of this composition.

In the later twenties, when oil well drillers were experiencing frequent failures of drill pipe, GRAHAM directed the development of a low-sulphur steel with from 2 to 3% manganese. This product, mildly air hardening, could be heat treated without liquid quenching, thus avoiding the difficult problems involved in quenching long pieces; oil field "twist-offs" were reduced toward the vanishing point.

Asked to develop a new grade of steel for tank armor during the recent war, GRAHAM proposed an intermediate-manganese steel, containing a small amount of molybdenum but no other strategic alloying element. Suitably heat treated, this grade developed a high rating of ballistic resistance.

Important as they are, manganese steels are but one of the many incidents in the career of HERBERT WINFIELD GRAHAM. Thirty-five years dedicated to progress in steelmaking, past-chairman of the A.I.M.E. Iron and Steel Division, HOWE Lecturer in 1947, in charge of all technical activities for J. & L.— to these high metallurgical distinctions of HERBERT W. GRAHAM has now been added a well-deserved A.S.M. Award for Distinguished Service in Alloy Steel.

Norman P. Goss

Consulting Metallurgist
Cold Metal Products Co.
Youngstown, Ohio

Citation "for discovering a commercial process for inducing directional crystallization in transformer and electrical sheet"

In 1925 Norman P. Goss, a young physicist, educated at Case School of Applied Science and University of Illinois, started to work at Cleveland Wire Works division of General Electric Co. Here for two years (and then for three more in the Cleveland research laboratory of American Steel and Wire Co.) he made thousands of X-ray patterns of wire and strip in various stages of processing, and witnessed various improvements in the product due to such systematic studies by a relatively new metallographic method.

Hence he embraced with enthusiasm an opportunity to put this new metallographic method to use on a project to make silicon-iron electrical sheet in continuous strip mills. Leon A. Beeghly of Cold Metal Products Co., who was promoting the Steckel mill, encouraged by Harry E. Sheldon, then president of Allegheny Steel Co., a principal manufacturer of electrical alloys, not only believed that transformer sheet could be made in continuous strip form, but also that a better sheet would evolve.

First work was done at Urbana. Prof. Jacob Kunz suggested that a torsion magnet be used for testing, since the sample need be no bigger than a dime — indeed, single crystals could readily be tested. Commercial transformer sheets were very weak, magnetically, compared with single silicon-iron crystals; some strip, after special annealing, had torque strength about half that of single crystals; unfortunately this clue led nowhere, for this was not associated with notably improved over-all magnetic properties.

In 1932 the work was transferred to Youngstown and Goss made a systematic study of rolling and heat treating schedules. By an optimum combination of processing conditions, he was able, three years later, to announce the commercial production of strip having the torque characteristics of a single crystal. Material was produced which easily saturated in the earth's field; a small strip could support more than its own weight of the same material when the two were placed in the vertical component of the earth's field! These remarkable properties could only be obtained in strips having 90% or more of the grains properly oriented with the direction of rolling.

Material, which up to then would be regarded as a laboratory curiosity, began to be made in tonnage; it revolutionized the design of transformers and reduced their weight by half, with notable savings in cost.

William E. Ruder

Head of the Metallurgical Division
Research Laboratory
General Electric Co.
Schenectady

Citation "for applying superior alloy irons and steels to electrical equipment and large steam turbines"

Bill Ruder joined the still-very-young Research Laboratory of the General Electric Co. in 1907, and has been there ever since. A graduate of Penn State in electrical engineering, he was quick to notice the vacuum melting furnace in the G. E. lab., and speculated on what vacuum melting might do to the properties of metals. That was the day Ruder became a metallurgist.

His curiosity was aroused about the cause of the wide variation in properties of iron-silicon alloys, which at that time were just beginning to find application in electrical apparatus, particularly transformers. He found the solution in the purity — especially the oxygen and carbon contents — and the grain size. He compared notes with Zay Jeffries, who was working on tungsten, and together they formulated the basic laws of grain growth and learned to make silicon steel crystals of any predetermined size. This led to the discovery of anisotropy in silicon steel (described by Ruder in the A.S.S.T. *Transactions*, 1925), which is the basis of the oriented silicon steel strip used so widely today.

Ruder's first patent, granted in 1914, concerned the manufacturing and processing of silicon sheet steel. He has maintained this interest in production problems and since 1933 has been a member of the Board of Directors of Allegheny Ludlum Steel Corp.

After having been in charge of magnetic and ferrous metallurgy research at G. E. for a number of years, Ruder became head of the Metallurgical Division in 1938. Since then he has brought to the Laboratory many metallurgists and physicists exceptionally well qualified to contribute to the basic science of metals.

Through 43 years of metallurgical research at G. E. and 17 years as a director of Allegheny Ludlum, Bill Ruder has made many important contributions to metallurgy, as well as unique improvements in the science and technology of magnetic alloys.

Maintain Operating Accuracy

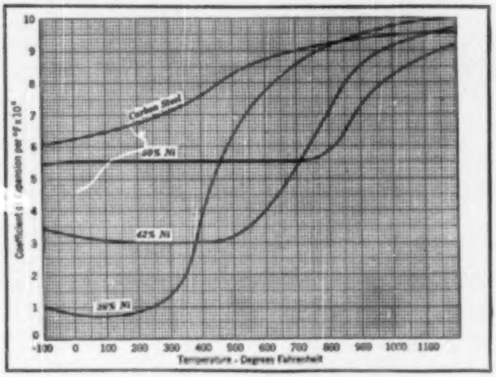
BY USING

Iron-Nickel Alloys

TO CONTROL THERMAL EXPANSION

Any desired coefficient of expansion, ranging from almost zero to a value greater than that of ordinary steel, may be obtained with the iron-nickel alloys. In addition, these alloys are strong, tough, ductile and possess a useful degree of corrosion resistance.

In wide use is a 36% nickel alloy... aptly named "Invar" because its dimensions remain almost *invariable* over the range of atmospheric temperature variations. However, as nickel content goes higher, expansion increases continuously. The chart, below, shows the thermal expansion characteristics of Invar and two other high nickel alloys, along with those of carbon steel for comparison.



FABRICATION

Like all austenitic alloys, those of the iron-nickel system respond well to plastic deformation, either hot or cold. They may be welded by any of the commonly used methods, and users report their machining characteristics are very similar to those of other high nickel alloys such as Monel® and Inconel®. A special, free-cutting grade is available to meet exacting machining requirements.

APPLICATIONS

Where dimensional changes with temperature must be minimized, or where such changes must approximate those of other materials of relatively low expansivity, iron-nickel alloys... sometimes modified by other alloying elements... are almost universally used.

For example... in thermostatic bimetal strip, Invar serves as the low expansion side for use up to moderately elevated temperatures. At higher temperatures, the 42% nickel alloy is commonly used. For the high expansion side, special alloys, containing 15-25% nickel, are used extensively because they develop nearly double the expansivity of iron. Iron-nickel alloys are also widely used in glass-to-metal seals, where expansivity of the glass must be closely matched. The 42% nickel alloy, sometimes with added chromium, is used with soft glasses. Hard glasses call for nickel alloys containing added cobalt.

Scores of other iron-nickel alloy applications include bases for giant telescopes, surveyors' tapes, radio condensers, parts for textile machinery and for numerous precision instruments and devices.

Industrial fields of usefulness for the iron-nickel alloys are far from exhausted. These unique materials can be of incalculable value in improving instrumentation and process control, and in the design of new devices. They are available in various forms including wire, rod, strip, sheet, bars and tubing. Send coupon today for additional information on the properties of iron-nickel alloys... they may be the means of improving your products, equipment, or process.

EMBLEM OF INCO SERVICE
TRADE MARK

The International Nickel Company, Inc.
Dept. MP, 67 Wall St., New York 5, N. Y.

Please send me further information about Iron-Nickel Alloys.

Name ______________ *Title* ______

Company ______________

Address ______________

City ______________ *State* ______

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK 5, N. Y

Exposures for Radium Radiography of Steel

By A. Morrison, National Research Council of Canada, Ottawa, Ontario

FROM the accompanying graphs the exposure time required for radium radiography of steel for several popular types of film can be obtained easily. These graphs are a revision, using the films now available, of the data originally presented in the A.S.T.M. Bulletin, No. 127, March 1944. Since a complete discussion was included in the previous publication, only a brief explanation of the graphs will be given here.

Steel thickness, in inches, is plotted along the horizontal axis of each of the lower graphs, and exposure factor along the vertical axis. By definition:

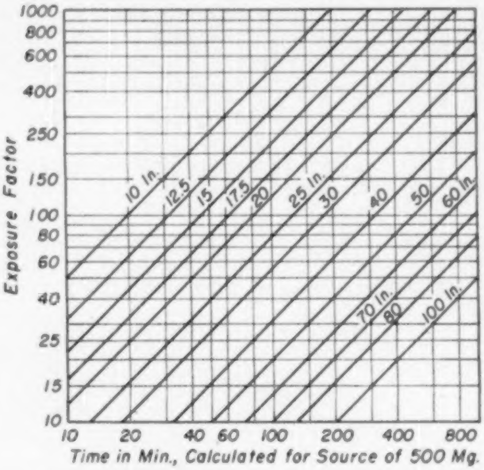
$$\text{Exposure factor} = \frac{S \times t}{d^2}$$

where S = size of radium source in milligrams
t = time of exposure in minutes
d = distance from source to film in inches

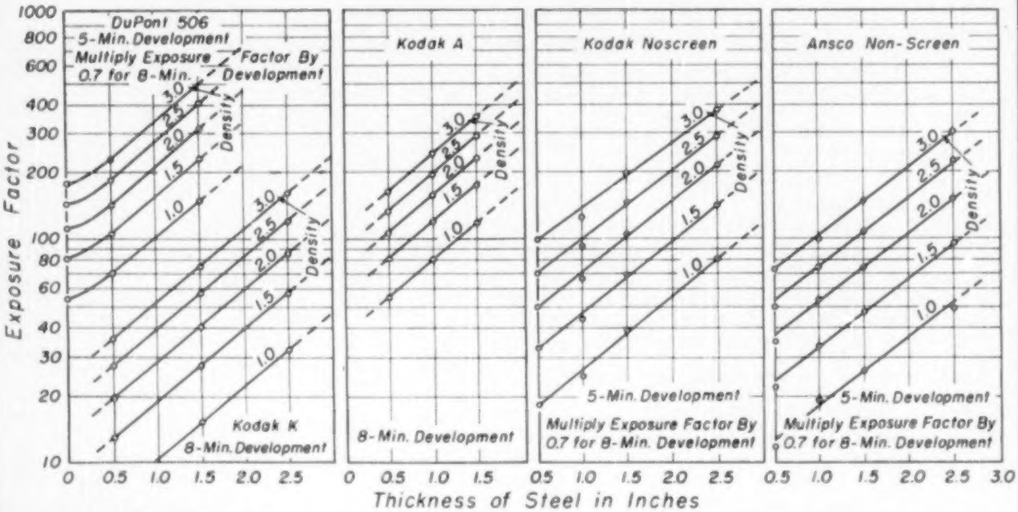
A series of exposures was made for each type of film with each of three or more thicknesses of steel, and from the measured densities of the developed films curves were drawn relating exposure to density. From these curves the exposure factors required for densities of 1.0, 1.5, 2.0, 2.5 and 3.0 were read. These exposure factors were plotted at the corresponding steel thicknesses and lines were drawn through the points of equal density. From the resulting graphs the exposure factor required to produce any density for any thickness of steel for each film can be determined.

Once the exposure factor has been determined, either the distance or the exposure time can be found, by choosing the other to fit the circumstances. For example, if a section of a steel casting 2 in. thick is to be radiographed, using a 300-mg. radium source, the exposure factor required for Kodak K film is 22 for density 1.0 and 60 for density 2.0. Assuming that density 2.0 is required for adequate sensitivity and that the source is to be 30 in. from the film, the time required can be obtained from $60 = \frac{300t}{900}$, or $t = 180$ min. If, for convenience, the exposure were to be made overnight, in 16 hr. (960 min.), the source-to-film distance can be found similarly: $60 = \frac{300 \times 960}{d^2}$. The distance d is then 69.2. The time or distance can be found with sufficient accuracy from the upper graph.

In the exposure graphs density 1.0 was chosen as the lowest at which good sensitivity can be obtained. The exact sensitivity at this density varies with the steel thickness and the film type. Density 3.0 was chosen as the highest at which the usual illuminators can be used. With high-intensity illuminators the maximum density can be much higher.



For 100 mg. multiply by 5.00
200 mg. multiply by 2.50
250 mg. multiply by 2.00
300 mg. multiply by 1.67
400 mg. multiply by 1.25
1000 mg. multiply by 0.50



CONDITIONS FOR ABOVE GRAPHS: Screens — 0.015-in. lead, front and back. Development — Kodak Rapid X-Ray developer, 68° F., standard agitation, duration as indicated on each graph.

Bausch & Lomb *Model L* Photomicrographic Equipment

Machining of Stainless Steel*

By E. Von Hambach
Research and Development Engineer
The Carpenter Steel Co.
Reading, Pa.

When securing revisions of the various chapters of "The Book of Stainless Steels" from the many cooperating experts, it was evident that the general discussion of machining included in the second edition of that book, written by Frank R. Palmer, could not be improved upon. Mr. Von Hambach, therefore, contented himself with specific information and recommendations concerning tool angles, speeds, feeds and coolants for the principal types of stainless steels and the principal machine shop operations.

THERE is no single set of rules or simple formula that will prove best for all machining jobs. The operator will have certain specifications for the work he is turning out. It is these requirements, together with the equipment he is using, that must determine the speeds, feeds, lubricants, and other factors that will do the job best.

"Production speed" is not only how fast the machine is running — or how many parts can be machined within a given period — but how quickly the entire run can be completed. The faster the cutting speed the more quickly the tools will wear — and the more frequently the machine will have to be shut down for regrinding of tools. Idle machine time is lost production time. Slower speeds with longer tool life is often the answer to higher output and lower costs.

Since the plan pursued in this article is based on the assumption that the reader is familiar with machine shop operations, it is only necessary to point out where the conventional practices vary from those on the plain carbon steels. (Frequently the free-machining grades are used as standard.) However, it has proven better to compare machining practices and machinability of the common types of stainless steels with familiar S.A.E. alloy steels, thus:

Stainless Type No.	Comparable Steel
410	S.A.E. 3140, 4140, 6140
420	S.A.E. 1095, 3150, 3312, 6150
420F	S.A.E. 2315, 2340, 2345
440	High speed toolsteel
440F	S.A.E. 1060, 1070, 1095
443	S.A.E. 3145, 3250, 4650, 6150
302	Copper-nickel alloys — except that 302 work hardens
416	S.A.E. 1030, 1120, X1340
430	S.A.E. 3140, 4140, 6140
430F	S.A.E. 1030, 1120, X1340
329	Copper-nickel alloys
303	S.A.E. 3120, 3145, 4615

In all tabulations the speeds and feeds will be the approximate limits for tools of 18-4-1 high speed steel. On some jobs it may be possible to use even higher speeds than those shown; on others lower than the minima will be necessary.

We will now take up the important machining operations one by one.

Turning

Turning operations on automatic screw machines and turret lathes involve so many variables that it is impossible to make specific recommendations which would apply to all conditions. Tool angles, cutting speeds and feeds given in this article are primarily starting points intended to be helpful in working out each job.

Table I gives the high and low range for turning and cutting various stainless steels. A good starting point may be taken halfway between the range given and then adjusting the speed upward or downward until the best results are obtained.

These speeds are recommended for stainless grades in various conditions, such as hot rolled, cold drawn or centerless ground, with hardness ranging from 187 to 250 Brinell. Dead soft annealed material is very tough and draggy; all stainless steels will machine somewhat better when they are slightly harder. Where higher physical properties are required, stainless can be machined quite satisfactorily at hardnesses up to Rockwell C-34.

Due to the slightly lower heat conductivity of stainless steels, more heat will accumulate at the cutting point than with ordinary steels. This heat is held locally in the work and tool. Therefore, these five simple points, carefully checked, often represent the difference between a slow or fast job — and a good or poor finish:

Table I — Turning
Surface speed in ft. per min.; Feed in inches

Type	Speed	Feed
410	80 to 115	0.003 to 0.008
420	40 to 80	0.003 to 0.008
420F	80 to 110	0.003 to 0.008
440	40 to 60	0.003 to 0.008
440F	70 to 90	0.003 to 0.008
443	80 to 110	0.003 to 0.008
302	40 to 85	0.003 to 0.008
416	110 to 140	0.003 to 0.008
430	85 to 115	0.003 to 0.008
430F	120 to 150	0.003 to 0.008
329	60 to 80	0.003 to 0.008
303	85 to 120	0.003 to 0.008

First, select as large a tool as possible, because the life of the cutting edge depends on good heat dissipation in the body of the tool, as well as into the work and cutting oil.

Second, to insure giving cutting edge maximum support, it is best to hold front clearance to the minimum, roughly 7 to 10°.

Third, top rake should be fairly steep. Tools with a 5 to 10° angle will generate less heat and be freer cutting. Generous chip curlers or chip breakers are also a decided advantage.

Fourth, use "finishing cuts" for very close tolerance. If the work cuts to a taper, it is recommended that turning be carried to 0.003 or 0.005 in. of finished size, then finishing with a light cut with the machine set at a fairly fast speed.

Fifth, all stainless steels take a good finish easily; therefore on the light cuts a good coolant that will carry away the heat is more important than a lubricant.

Grinding the tools properly is particularly important in machining stainless. Generally, the straight chromium, free-machining types — such as Types 416, 430F, and 420F — machine easiest of all. However, the regular chromium-nickel (18-8) types, due to their tough, draggy condition and work hardening characteristics, require turning tools ground with the top rake angle on the high side (see Fig. 1). Smaller angles tend to "hog in" and work harden chromium-nickel grades. To prevent rubbing, side clearance angles may have to be increased.

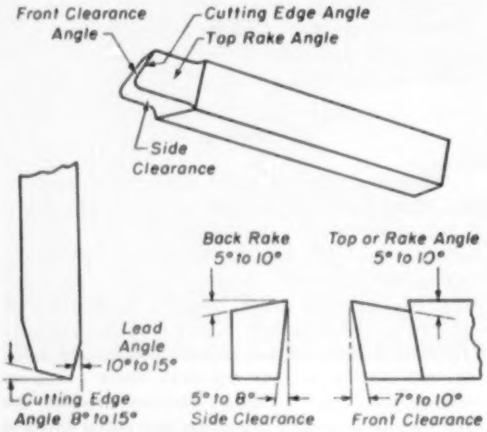
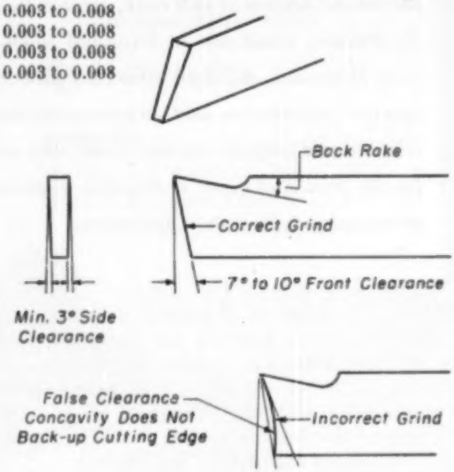


Fig. 1 — Suggested Angles on Turning Tools

Fig. 2 — Flat Bladed Cut-Off Tools



Stainless steel types other than the free-machining will tend to produce long, stringy chips which can be troublesome by piling up on the tool and clogging the work. By grinding a "chip curler" into the top face of the tool, this difficulty is quickly overcome. In addition to controlling long chips, a properly ground chip curler produces a lifting effect on the chip, so that there is less friction on the cutting edge of the tool. Free-machining types do not require as deep a chip breaker or curler. There are no standard rules or designs regarding chip curlers; the depth of cut

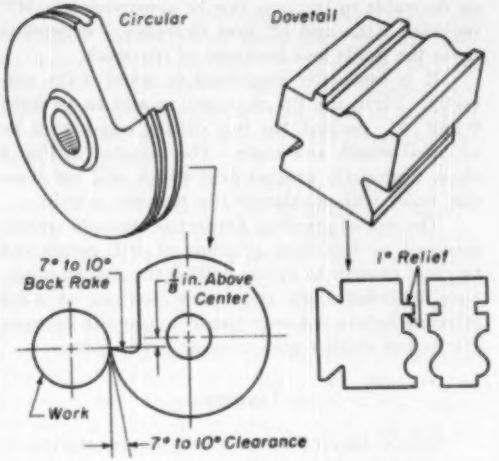


Fig. 3 — Circular and Dovetail Form Cutters

and feed govern its width and depth, because the heavier the chip the deeper the curler will have to be to break it. Proper grinding of chip control grooves is as important as grinding the tool.

Parting or cut-off tools of the standard type (either flat blade or circular) are widely used and offer few, if any, problems on any stainless job. These tools are usually supplied with sufficient bevel for side clearance. They must be ground (as shown in Fig. 2) to provide for top rake and front clearance. Circular cut-off tools are usually employed in automatics on large production screw machine jobs for small diameter work. In them, top rake is usually the same as for beveled blade cut-off tools. Because cut-off tools are frequently fed into drilled or threaded holes, the circular type will be more rigid and withstand proportionally greater shock than the flat blade type. If the cut-off or parting is deep, and the work binds or galls the tool, it may be necessary to grind 1 to 2° additional on the side clearance angle.

Form tools are usually of the circular or dovetail type as shown in Fig. 3. The circular form tools work to best advantage on screw machines, and are therefore preferred by many operators.

The tool designer can play an important part in the life and efficiency of form tools because their speeds and feeds are largely governed by the width of the tool in relation to the size of the bar, plus the amount of overhang and the contour. The circular type, when used for deep forms, must be designed to compensate for lack of side clearance. Frequently, it is advisable to allow side clearance beyond the allowable limits of the finished piece. When this is done, a shave tool will have to be added as another operation or, if extra spindles are not available, this can be incorporated with the cut-off. Where close tolerance and fine finish are necessary, use a shave tool with a light cut at a fast speed. Selection of tool-steel for this operation is important.

Drilling

This is one of the most common and yet most important jobs of machining, as later operations are frequently located from the first drilled hole. Accuracy, therefore, is vital. Chips must be kept away from the work, because they can act as an abrasive and dull the drill.

When laying out holes on stainless steels, particularly the 18-8 types, it is advisable to use a sharp, three-cornered punch rather than a prick punch, to minimize work hardening the material at the mark.

To relieve chip packing and congestion, drills must occasionally be "backed out". Roughly, the rule for successfully drilling deep holes in stainless is to take three to four times the diameter of the drill on the first bite, one or two diameters on the second bite, and three quarters to one diameter on the third bite.

When drill size permits, a groove should be ground parallel to the cutting edge in the flute for chip clearance; deeper holes can be drilled on each bite and tool life increased. If the hole "runs out", maintain concentricity by driving both work and drill.

Rates of feed are given in Table II, the column headed "Feed" covering drills ranging from ¼ to ½-in. diameter. On smaller diameters, the feed should not be so high. For example, for ⅛ to ¼-in. diameter, feed would be 0.002 to 0.004 in. On sizes over ½ and up to and including 1-in. diameter, the feed would be 0.007 to 0.015 in.

On small drills, breakage will be excessive if drills are

Table II — Drilling
Surface speed in ft. per min.;
Feed in inches for ¼ to ½-in. drills

Type	Speed*	Feed
410	35 to 75	0.003 to 0.007
420	30 to 60	0.003 to 0.007
420F	70 to 90	0.003 to 0.007
440	20 to 40	0.003 to 0.007
440F	50 to 70	0.003 to 0.007
443	35 to 75	0.003 to 0.007
302	15 to 40	0.003 to 0.007 (Use constant feed)
416	70 to 110	0.003 to 0.007
430	35 to 75	0.003 to 0.007
430F	70 to 115	0.003 to 0.007
329	20 to 40	0.003 to 0.007 (Use constant feed)
303	35 to 85	0.003 to 0.007 (Use constant feed)

*Bases: High speed drills; for carbon drills reduce speeds by 40 or 50%.

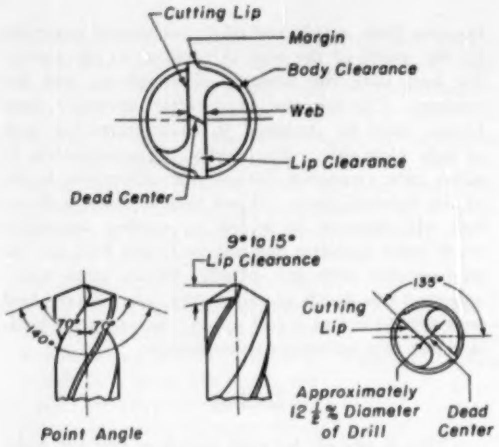


Fig. 4 — Angles for Drills

not run fast enough. Bear in mind a $\frac{1}{16}$-in. drill cutting at 40 surface ft. per min. should turn at a spindle speed of 2445 r.p.m.

Do not let drill dwell during cutting, particularly on the chromium-nickel types such as Type 302 and Type 303. If the drill dwells or rides, it glazes these work hardening grades and it then becomes very difficult to get under this hardened surface.

For general-purpose drilling, twist drill makers produce a special drill for stainless steel. It has a shorter flute and over-all length than regular drills and is therefore heavier and stronger. As sold from stock, this type of drill is generally pointed with an included angle of 140° (see Fig. 4). Use a cotter-pin drill when necessary to drill small cross holes in the heads of bolts, screws or pins; it is a more heavily constructed drill which stands abnormal strains and the shorter helix angle of the flutes aids in removing the chips.

It is recommended that drills be chucked for shortest drilling length. Long drills tend to whip and flex and may easily break or cause inaccurate work. Some jobs require exceptionally deep drilled holes (eight to ten times the diameter), and short chucking is impossible.

In such cases, special drills known as "crankshaft hole drills" are well worth trying because of their short spirals. These drills were originally designed to drill long oil holes in forged crankshafts and connecting rods. They are made with a very heavy web and a higher spiral or helix angle than regular drills. They usually come with a notched-point type of web thinning. Commercial attachments set to grind this notched type of point are available. As purchased, these drills usually have the points ground to 136° included angle, with a heel clearance of 9°. For a particular job it may be desirable to increase this to approximately 140° included angle and 12° heel clearance — depending upon the grade and hardness of the work.

It is especially important to grind drills correctly. First, the lip clearance should be between 9 and 15°. Second, the two cutting edges must be of equal length and angle. The sketches in Fig. 4 show a properly ground drill which will cut true-size holes with maximum life between grinds.

The use of grinding fixtures is strongly recommended; no free-hand grinding of drill points can be close enough to insure getting the correct clearance, included angle and center location. A good grinding fixture not only means longer life between grinds but cleaner and more accurate holes.

Tapping

Before tapping operations can be started, a hole must be drilled. There has been a tendency on the part of some to overlook the important part that the hole bears in relation to securing a finished tapped hole of the desired quality — particularly in production operations. Do not forget that the tap is simply a cutting tool and is not a corrective for an undersized or poorly drilled hole. Taps require the same consideration and care as any other sharp edged tool. Good screw threads cannot be obtained unless the job is carefully considered and the right tap carefully selected. "Any old tap" won't do.

When laying out the job the percentage of thread depth must be determined and this should be governed by the diameter and pitch of tap, plus depth of tapped hole, plus toughness or hardness of material. There is a definite limit to the strength of a tap and the amount of metal it will cut or move. Therefore, on the tough and harder materials tap life is increased when a lower percentage of thread depth is cut. Under such conditions it will be found economical to do a two-step operation — first, rough out the hole with an undersized tap, and then finish to size with a second tap.

Customary manufacturing practice usually provides for a depth of thread not less than 62% and not more than 75%. A 100% thread depth is only 5% stronger than a 75% thread, but requires three times as much power, and a bolt on a 50% thread will break before the thread will strip.

A general rule in laying out a new job is to use a 100% thread where the thickness of metal is one half or less than the diameter of tap. Use a 75% thread where thread depth is up to two times the tap diameter. On jobs where thread depth exceeds twice the diameter of tap, it is economical to use only 50% thread. This greatly increases tap life and cuts the power required.

Tap drill sizes are often selected from old "standard" tables which serve their purpose well for many run-of-mine jobs. However, for tapping stainless, particularly where fine pitches are required, it has been found that some of the drill errors are too great — therefore the following formulas are given.

It is sometimes an advantage to divert from standard decimal drill sizes to millimeter sizes — and in extreme cases to have special drills made. Even a special drill, as a general rule, costs much less than a tap. As an example, take the common No. 8-32 size, where as close to a 75% thread as possible is required. The No. 29 (0.1360-in.) drill gives only a 69% thread depth, which is not enough. The No. 30 (0.1285-in.) drill — the next size — gives an 87% thread depth, which is too much. By using a 3.40-mm. (0.1339-in.) drill you will get a 74% thread depth.

It is advisable, therefore, to check each job according to these formulas:

Formula No. 1, for Obtaining Tap Drill Size

$$\text{Outside diameter} - \frac{0.0130 \times \%\ \text{full thread}}{\text{No. of threads per in.}} = \text{drill size}$$

EXAMPLE: For ¼-in. x 20 thread:

$$0.250 - \frac{0.0130\ \text{in.} \times 75}{20} = 0.2013 \text{ or No. 7 drill}$$

Formula No. 2, for Obtaining Percentage of Thread a Given Drill Will Produce

$$\frac{(\text{Outside dia.} - \text{drill size}) \times \text{No. of threads per in.}}{0.0130} = \%\ \text{of full thread}$$

EXAMPLE: For ¼-in. x 20 thread:

$$\frac{(0.250 - 0.201) \times 20}{0.0130} = 75.4\%\ \text{thread}$$

Type of tap selected will depend largely on the "class of fit" required. The following four classes are standard:

Class 1 — Loose Fit	Class 3 — Medium Fit
Class 2 — Free Fit	Class 4 — Close Fit

Class of fit also determines whether it is necessary to use cut thread tap, ground thread tap, or a precision ground thread tap, with either No. 01, No. 1 or No. 2 tolerance. A cut thread tap is used for Class 1 fits, ground thread taps are used for Class 2 fits, and precision ground taps for Class 3 and Class 4 fits.

Chip removal is important for tapping to close tolerances. Without a place for the chip to go, no hole could be tapped. When the wrong tap is selected, chips crowd into the flutes; therefore, flutes should not be too shallow or the lands too wide. Often the power required to break packed chips is more than that required to cut the thread. When this happens, the tap, being weaker and working against the power of the machine, will break. Chip packing also causes taps to cut oversize threads. Chips from tapping can be disposed of, the same as on any other cutting tool.

Performance of taps in stainless steel is very greatly influenced by the rake angle of the cutting face. Sketches shown in Fig. 5 are average recommendations. For some types of tapping it may be necessary to alter the cutting face design or angle. Occasionally, due to a combination of variables on certain types of work, the hook grind, which normally is best, will not give satisfactory results. In such instances, an interrupted thread tap with an uneven number of flutes has licked the problem (particularly where the tapping machine lacks power) since it requires 40 to 50% less power than regular taps. Roughness on the back face of the thread can sometimes be avoided by a negative grind on the heel of the tap. This prevents tearing the threads when backing the taps out.

Table III — Tapping Speeds

TYPE	SPEED
410	10 to 25
420	10 to 20
420F	15 to 25
440	5 to 15
440F	10 to 20
443	15 to 25
302	10 to 20
416	15 to 35
430	10 to 20
430F	15 to 40
329	5 to 15
303	15 to 30

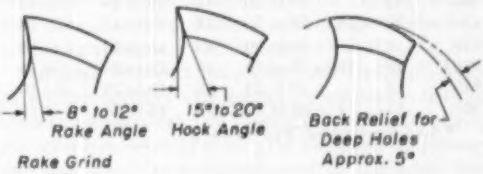


Fig. 5 — Average Recommendations for Regrinding of Taps

As has been remarked about drills, it is very poor practice to regrind taps free-hand, particularly the chamfer. The following angles are generally recommended for grinding the chamfer:

Taper taps — 4 to 5°, or 8 to 10 threads
Plug taps — 9 to 10°, or 3½ to 4½ threads
Bottoming taps — 30 to 35°, or 1½ to 2 threads

Lubrication is frequently given too little thought. While the sulphur-base oils have proven most successful, specific compositions or ratios of sulphur-base oils to paraffin-base oils are a definite requirement on difficult jobs. After the best mixture has been determined, it is equally important that the *flow* of the lubricant to the taps and the work be considered. It is often desirable to use two streams, one on each side of the tap. Start the flow before the tap starts to cut and do not shut it off until after the cut is finished.

Threading

Thread chasers for self-opening die heads are made of high speed steel, and the standard commercial chasers generally have a long and satisfactory life — *provided* they are kept sharp and correctly ground for the materials they are to cut.

Maximum production and smooth finished threads are the two important requirements in thread chasing. To secure best results it is frequently necessary for the operator to adapt his set-up to each job. If the speed is too slow and an increase of 10 or 20% does not cut down the tool life, this will mean that production can be greatly increased simply by changing speeds. There are times, however, when the job is set up too fast; if such is the case, reducing the speed will prolong the tool life, show a gain in production and improve the quality of the work produced.

Table IV — Threading Speeds for Threads of Various Designs

High and low limits in surface ft. per min.

Type No.	Acme	National Fine	National Coarse*	General	Fine Threads
410	12	10 to 20	18	10 to 20	5 to 10
420	12	10 to 20	18	10 to 20	5 to 10
420F	12	10 to 20 or 25	18	12 to 25	5 to 10
440	12	10 to 20	18	10 to 20	5 to 10
440F	12	10 to 20 or 25	18	12 to 25	5 to 10
443	12	10 to 20	18	10 to 20	5 to 10
302	12	10 to 20	18	10 to 20	5 to 10
416	12	10 to 20 or 25	18	12 to 25	5 to 10
430	12	10 to 20	18	10 to 20	5 to 10
430F	12	10 to 20 or 25	18	12 to 25	5 to 10
329	12	10 to 20	18	10 to 20	5 to 10
303	12	10 to 20 or 25	18	12 to 25	5 to 10

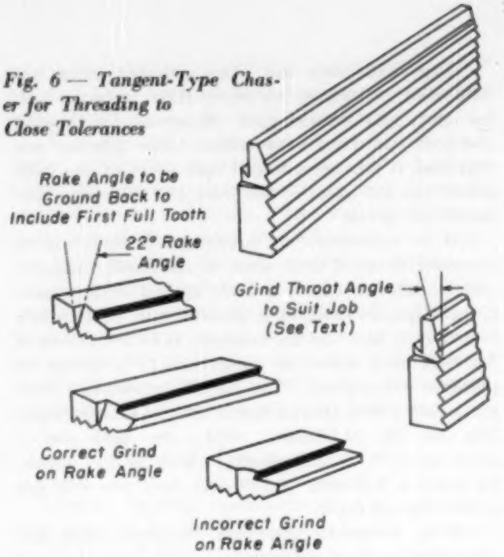
*Also for tapered pipe threads.

Table IV gives the recommended speeds. The wide range in its recommendations is due to the possible use of any one of four types of chasers, as described below, and the variable conditions of material threaded. Slightly harder material (210 to 240 Brinell) will thread easier than dead soft annealed stainless steels. Each job has to be developed for best production results, keeping in mind speeds should be increased or decreased in small steps. All recommendations, as in the other tables, are based on standard high speed tools.

The four principal types of chasers used for threading stainless steel are:

1. Most generally used chaser for close tolerance threads is the tangent type, shown in Fig. 6. It is particularly adaptable for heavy-duty jobs, such as Acme threads, or for long coarse threading. The tangent type of chaser seems to hold the thread better on heavy-duty work and gives good

Fig. 6 — Tangent-Type Chaser for Threading to Close Tolerances



chaser life between grinds. Wherever possible use a 20° throat. For National coarse and fine threads, where the threads do not run into a shoulder, a 15° throat is desirable. Single Acme threads require a 12° throat angle and double Acme threads a 7° throat angle.

2. The circular type is really the universal thread chaser, as it is adaptable to all types of threads and will work equally well on tubing. This type of chaser, Fig. 7, generally works well with a 25° throat angle.

3. Insert type of chaser (Fig. 8) is widely used because it produces very good threads at a low cost. A 20° throat angle is usually recommended.

4. The radial type of chaser (Fig. 9) has been more widely used on ordinary steels than on stainless. It will produce very smooth threads, inasmuch as it is ground to follow the shape or contour of the threaded piece. On screw machine jobs requiring extremely fine threads, this type of chaser has been used successfully on stainless. Radial chasers seem to work best on average jobs with a 20° throat angle.

Throat angle or chamfer will vary slightly for each of the chasers described according to the type of thread being cut and the grade of stainless used. In general, it is advisable to use from 1½ to 3-thread chamfer on the throat. This will usually produce a smooth, fine finish thread — and increase chaser life between grinds.

Advantage of using a long throat angle is that each tooth takes a smaller bite and consequently produces cleaner threads. An examination on one job, for example, shows that a 45° throat angle produced a chip approximately 0.018 in. thick,

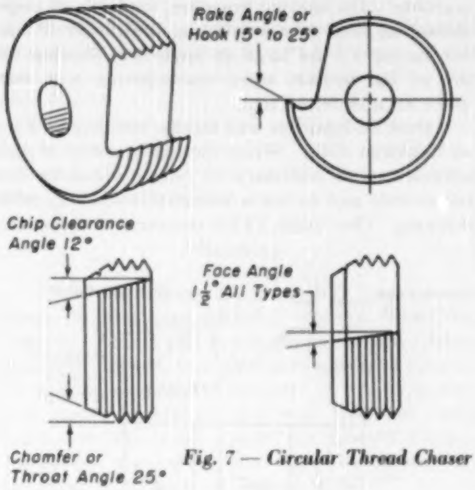


Fig. 7 — Circular Thread Chaser

while a 15° throat angle produced a chip only 0.0065 in. thick.

General rule-of-thumb recommendations for cutting threads is 18 surface ft. per min., but regardless of the type of chaser being used, speeds will vary somewhat with the type of thread being cut. Acme threads are usually cut at 12 surface ft. per min.; American National coarse threads or tapered pipe threads at 18, and National fine threads up to 20 surface ft. per min. While these are not the maximum speeds, they are the ones that usually give longest chaser life per grind.

Where extremely fine threads are required, it might be desirable to drop the speeds down to 5 or 10 surface ft. per min. Also, when cutting fine threads, an advantage will be found in diluting the heavy sulphurized oil with paraffin oil — generally one part sulphurized oil to five parts paraffin. Oil must be kept clean and free of chips. If fine chips float in the oil and get into the chaser, they will ruin the threads.

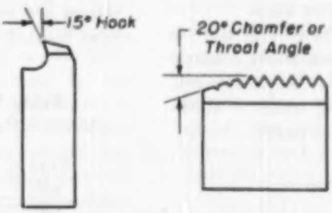


Fig. 8 — Angles for Insert Chasers Used on Stainless Steel

Milling

Speeds for milling are very nearly equal to those for turning. Roughly, a good starting point for milling stainless is 10 to 15% slower than speeds for the nearest equivalent in ordinary steels. Recommendations are given in Table V.

As a guide for appraising the feed of the tool, examine the work — if the cut is too light, the tool will burnish the work and the cut should be increased; if the cut is too heavy, tool life is shortened and a lighter cut should be taken. Depth of cut and speed of feed are also regulated by the type of machine tool being used. On modern milling machines, cuts can usually be increased to the maximum power of the machine.

As a general rule, smoothest finishes are obtained with helical or spiral tooth cutters running at high speed. They cut with a shearing action and as a result cut more freely and with less chatter than cutters with straight teeth. The coarser the teeth, the better; coarse tooth cutters work under less stress and permit higher speeds than fine tooth cutters. They reduce cutting pressure and the fact that there is more space between the teeth helps to clear away the chips.

Heavy cuts must run slower than light cuts since they generate more heat. For example, a roughing cut would be run with heavier feeds and slower speeds than those used for the lighter finishing cuts. But no matter what the operation, both work and tool must be flooded with a good sulphurized-base oil, properly diluted with paraffin-base oil. Milling generates considerable heat which must be carried off by the lubricant or the work will distort and the tool edges will dull or chip rapidly.

Sufficient clearance behind the cutting edge of every tooth is necessary to avoid a rubbing or burnishing action. Hogging-in and excess vibration generally indicate too much rake or not enough clearance — and possibly too high a cutting speed. Use short, stubby arbors with large diameters wherever possible. Rigidity improves the job.

Figure 10 shows rake angle and width of land, as well as primary and secondary clearance that is standard procedure for regrinding milling cutters for stainless steel jobs to give sufficient clearance and strength. On cutters up to 4 in. diameter, use

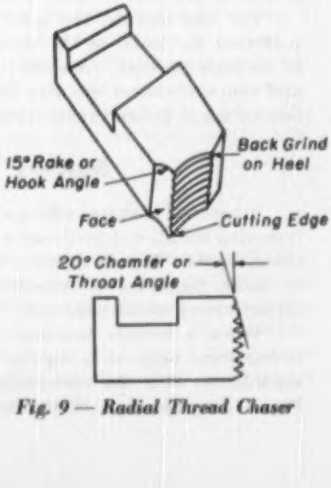


Fig. 9 — Radial Thread Chaser

the maximum clearance shown in the sketch, remembering that small cutters take a greater clearance angle than large cutters.

When using plain milling cutters of cylindrical shape, with teeth on their outer surface only, it is advisable to go to a helical tooth cutter on mills over ¾ in. wide. Helical teeth cut with a shearing action; they not only lessen chatter but give a finer finish. Under ¾ in. wide, cutters with straight teeth are satisfactory.

Table V — Milling Speeds

Type	Speed
410	70 to 105
420	35 to 70
420F	70 to 100
440	35 to 80
440F	65 to 80
443	70 to 100
302	35 to 65
416	100 to 125
430	70 to 105
430F	110 to 135
329	55 to 70
303	75 to 110

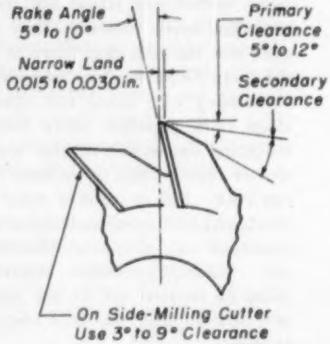


Fig. 10 — Rake Angle and Clearances for Regrinding Milling Cutters

Straddle or side-mill cutters have cutting teeth on each side, as well as on the circumference or periphery. Such cutters will mill on both sides of a part, or mill shallow slots. For milling shoulders it is common to use half-side cutters, which have teeth only on one side and on the circumference.

Milling deep slots in stainless steel sometimes involves chatter, binding and jamming of wide chips. Such troubles can be eliminated by using a cutter with staggered teeth. Alternating teeth take a smaller bite and produce a shorter chip.

For end milling, the solid shank end mill is preferred for work on the stainless steels because of its high strength. Angular, gear tooth, convex, and concave cutters are also being used on stainless by many producers of stainless parts.

Broaching

Broaching stainless offers a means for rapidly removing metal, and produces a finish to close precision limits. Broach manufacturers are equipped to make these tools; therefore, consult a good manufacturer about your job.

When a broach becomes dull, it should be resharpened only on a regular broach grinder in accordance with the recommendations shown in Fig. 11, or returned to the manufacturer to be reground. On internal broaches, the back-off angle should be held to a minimum, preferably 2° and not exceed 5°; too large an angle will shorten the life of the broach, since resharpening will then make an undersized tool.

Most all broaches will handle stainless as hard as Rockwell C-35. When cutting material at this hardness, it is necessary to reduce speed in feet per minute and to use a lubricant with very little thinning. (See Table VI for recommended speeds.)

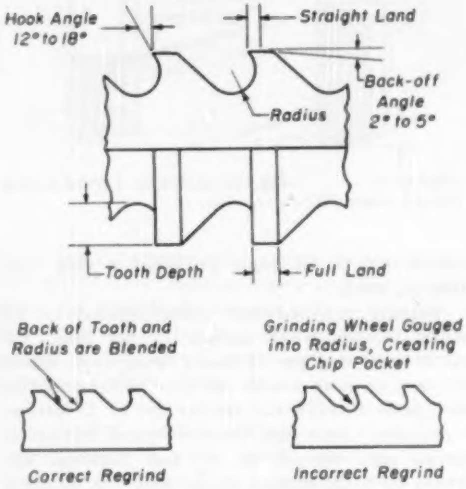


Fig. 11 — Angles for Resharpening Internal Broaches

Broaches have cut stock harder than Rockwell C-35, but the cost is usually prohibitive because the broach dulls rapidly and not enough pieces are produced between grinds. Where higher hardnesses are required, pieces are first broached, then heat treated. To remove any light scale and cor-

Table VI — Broaching Speeds and Cuts
Speeds in ft. per min. (low to high); Cut is per tooth for round broaches

Type	Speed	Cut
410	10 to 20	0.001 to 0.005
420	8 to 15	0.001 to 0.005
420F	10 to 20	0.001 to 0.005
440	8 to 12	0.001 to 0.005
440F	8 to 15	0.001 to 0.005
443	10 to 20	0.001 to 0.005
302	8 to 15	0.001 to 0.005
416	15 to 25	0.001 to 0.005
430	10 to 20	0.001 to 0.005
430F	15 to 25	0.001 to 0.005
329	8 to 12	0.001 to 0.005
303	10 to 20	0.001 to 0.005

rect some distortion resulting from heat treating, a special broach known as a "hard gear" broach can be used when machines with enough power are available.

Proper lubrication and cooling are important. Sulphur-chlorinated oils, "cut" with paraffin-base oil rather than with water-soluble oils, are desired when broaching stainless steels.

Reaming

It will be noted that Table VII gives a wide range in the recommended cutting speed for reamers. This is due to a combination of variables that exist on this type of work, governed entirely by tolerances and the quality of work desired. The higher speeds are generally used for sizing work, and the lower speeds for smooth finishes. As in all the tables, the recommendations are based on 18-4-1 high speed steel tools.

Table VII — Speeds and Feeds for Reaming
Speed limits are in surface ft. per min.; Feeds per revolution are for ¼ to 1-in. reamers

Type	Speed	Feed
410	20 to 60	0.003 to 0.008
420	20 to 60	0.003 to 0.008
420F	30 to 100	0.003 to 0.008
440	20 to 60	0.003 to 0.008
440F	30 to 90	0.003 to 0.008
443	20 to 60	0.003 to 0.008
302	20 to 60	0.003 to 0.008
416	30 to 120	0.003 to 0.008
430	20 to 60	0.003 to 0.008
430F	30 to 120	0.003 to 0.008
329	20 to 60	0.003 to 0,008
303	30 to 100	0.003 to 0.008

On non-free-machining chromium-nickel grades (18-8), ample material must be left to permit the operator to take a definite cut. This is a protection against dragging or riding of the tool, which produces rapid wear and failure of the reamer. Allowing the reamer to take a definite cut also avoids burnishing, which results in undersize holes and rapid reamer wear. Better results are secured if reamers are mounted in floating holders. Narrow lands and stoned cutting edges are recommended; stoning the edges of reamers is of particular importance, for any coarse grinding marks remaining on the reamer leave their pattern in the finished hole.

For good reaming of the stainless steels, the high speed spiral fluted reamer with a helix angle of approximately 7° is recommended. There is less tendency for this type of reamer to chatter, and the chips clear well. A left-hand (reverse) spiral reamer running in the opposite direction to the work is recommended. Right-hand spiraling of the flutes helps the tool to cut more freely, but makes it feed into the work too rapidly.

Suggested clearances and cutting rakes shown in Fig. 12 apply to either solid or inserted-blade tools. These clearances avoid binding. High speed steel reamers only are recommended.

The matter of taper reaming arises frequently. Experiments indicate that when only commercial finish is required, any one of the standard taper reamers ground for stainless will do a satisfactory job. The hole must first be carefully drilled or bored. Where fine finish and close tolerance are demanded, operators claim they can use taper turning attachments at satisfactory costs; however, the proper method of finishing a tapered hole is a mathematical problem on high production jobs.

Reamers, unlike drills, cut on the sides instead of on the end. Because the cutting edge is so long,

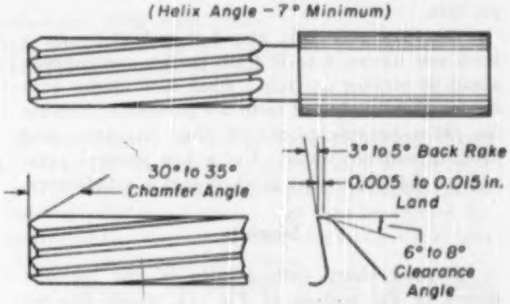


Fig. 12 — Angles for Regular Stub Screw Machine Reamer of High Speed Steel

slower speeds and correct lubrication are necessary to avoid overheating the tool. Besides being a good lubricant, the oil must also be a coolant to carry away the heat that would otherwise burn the cutting edges of the reamer. Reaming produces slivers and very fine chips which can float in the lubricant and get into the work very easily. Efficient oil filters are a necessity.

Filing Stainless Steel

Filing stainless is seldom given much thought, primarily because the job can always be filed somehow or other with general-purpose files. This problem was investigated by various file manufacturers who are now making special files. Such files are marked "For stainless steel", and should be specified for best results.

Straight chromium types and the free-machining grades of stainless present very little difficulty; it is the 18-8 type which requires care, and the important thing to remember is to take enough of a bite to keep the file cutting. Otherwise the surface will become glazed and hardened. When filing stainless, use a light pressure and a slow steady stroke. Fast strokes and "laying hard" on the file only make it more difficult to cut, and wear out the teeth faster.

Sawing

Fortunately, saw cutting at no time has really presented any major problem. There are times when stainless bars must be sawed, and for those who are not familiar with the operation these suggestions are offered:

On bars up to and including 1 in. in thickness, a band saw works very well. Use a saw blade with 14 teeth per in., running at a safe speed of 110 ft. per min. If band saws are used with over 15 and up to 18 teeth per in., reduce the speed to 100 ft. per min.

On bars over 1-in. round it is best to use a hack saw having 6 to 10 teeth per in. and running about 60 strokes per min. Hack saw blades with the smaller number of teeth are preferable because the latter provide plenty of chip clearance, and packing will not occur. Use a low positive pressure on the blade. Any good coolant is satisfactory.

Stoning

A good sharp cutting edge is like the one shown at the bottom of Fig. 13, which has an unbroken line that carries an equalized load. Compare this with the upper edge shown — here high spots or peaks carry the load. These unsupported peaks cannot bear the brunt of such stresses for long and therefore break off, leaving flat spots that rub and tear the work. This condition also generates excessive heat through friction, which frequently burns the tip of the tool. The ultimate result is increased down-time for regrinding.

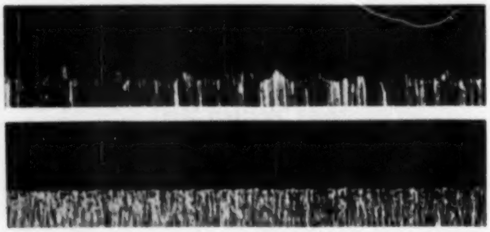


Fig. 13 — Jagged Cutting Edge of Carefully Ground Tool (Above) Is Smoothed by Adequate Stoning. Magnification 100 diameters

No machine operator will question the value of a sharp cutting edge. The longer this edge remains sharp, the longer the tool will cut before it needs to be reground — and it will produce a better finish on the job. A tool with a "rough coarse" grind will transfer its mark to the work, giving a poorer finish. It also has a tendency to decrease the life of the tool between grinds.

Close observation on cutting tools reveals that by careful grinding and stoning, tool life is increased from 10% to as high as 60% between grinds. Results observed are finer quality of work produced, increased number of pieces between grinds, less power consumption and fewer grinding wheels used.

The most commonly used grinding wheel in tool shops today is the 60-grit wheel. After the rough grind is made, some operators take one or two passes over the work with practically no feed. This gives a fairly good edge and finish. After the worn edges are removed with a 60-grit wheel, experience indicates it is desirable to go one step further and finish up with a very fine (120-grit) wheel and stone.

Advantages obtained from careful grinding and stoning may be summed up as follows:

1. Stoning produces an exceptionally good, sharp cutting edge that carries an equalized load along its entire length.

2. Stoning increases tool life from 10 to 60% between grinds.

Lubrication

Because all metals tend to weld under the combined action of pressure and temperature, chips weld to the tool. Lubrication reduces frictional heat (temperature), metallic welding, and scuffing.

Sulphur has been recognized for years for its ability to cool and prevent seizing. As a result, properly blended sulphurized-base oils are now the standard lubricant and coolant for machining all types of stainless steels. Oil manufacturers recommend two types of sulphurized oil:

1. A sulpho-chlorinated petroleum oil containing active sulphur and approximately 8 to 10% fatty oil. Viscosity is about 200 sec. at 100° F.

2. A sulpho-chlorinated petroleum oil containing active sulphur without a fatty base oil. Viscosity is approximately 130 sec. at 100° F.

Oil No. 1 is generally used for the non-free-machining types of stainless. Oil No. 2 is usually preferred for the free-machining grades. Both of these oils, depending on the work being done, can

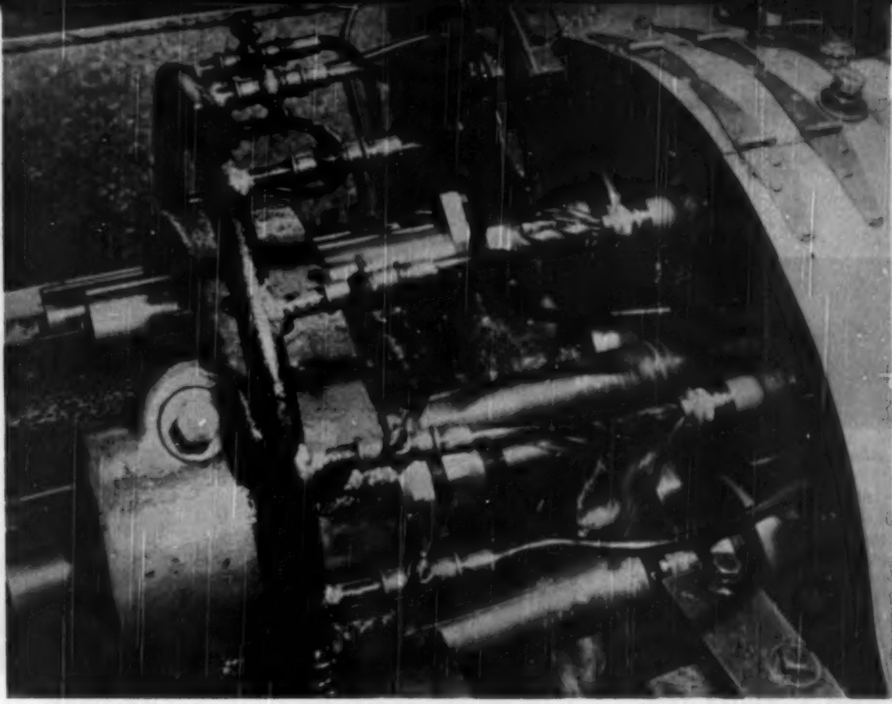


Fig. 14 — Six-Spindle Gridley Automatic With Feed Lines Rearranged to Direct Oil to the Cutting Edges. Such efficient use of lubricant and coolant increased tool life 35%, grind to grind

either be used straight or diluted with a blending oil — the best of which is paraffin — usually starting with a mixture of 1 to 1.

Watch the tools and if excessive wear is observed, paraffin blending is needed. If the chips weld to the tool or the tool burns, too much paraffin blending oil is present in the mixture, and an addition of more sulphur-base oil of either Type 1 or 2 is indicated.

A good rule-of-thumb for starting new jobs is to remember that the tougher the steels (such as Types 302, 329, 420, 440) the more sulphurized oil is needed. For free-machining steels (such as Types 303, 416, 430F) the mixture can contain a larger percentage of paraffin-base oil.

Efficiency of the coolant and lubricant is governed by the size and form of nozzle through which it is delivered, as well as direction, position, pressure and volume of the supply of the oil.

The best oil is no good unless it constantly floods the work and the tool at high pressure. Each stream should play directly on the work and the cutting edge of the tool. Such a set-up as Fig. 14 will show remarkable oil economy, and produce excellent finish. Further, it will eliminate a fault encountered where the tool holder, moving into the work, intercepts the flow of the coolant.

In general, temperature of the lubricant or coolant should not exceed 140° F. For best results the temperature should be held within the range of 75 to 125° F. One way to eliminate the problem of hot oil is to make certain a generous sized tank is full at all times. Oil loss is caused by evaporation, adherence to the chips and work, and leaks in the circulating system.

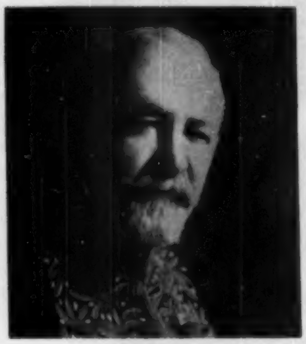
Frequently fine finished, ground and polished bars are shipped from the mill with a light oil sprayed on them. This is to prevent scratching or marring the bars during transportation. Such oils are not good lubricants and repel the cutting oils. Therefore, to get the best out of cutting oil, any excess "shipping oil" should be removed before machining.

Proper lubricants and coolants, properly applied, assure longer tool life, heavier cuts, higher speeds, better finishes and fewer scrapped parts.

Conclusion

It is realized that machining is an exceedingly complicated art and science. Only the most general hints can be given in such an account as this. If the above information does not answer the question which is giving trouble, consult your steel manufacturer or the tool manufacturer. These firms have field engineers with broad experience, and their representatives can usually diagnose the trouble and prescribe the cure.

Movements Among Metallurgists



Albert M. Portevin

Dean of French metallurgists, **Albert M. Portevin** ⊜ has been awarded the platinum medal for service to metallurgy, highest award of the British Institute of Metals. The president of the Institute, in his presentation remarks, alluded to the versatility and many-sidedness of the recipient's genius (well known to Americans through his "Correspondence" published at intervals since 1930 in *Metal Progress*), his illustrious work in all branches of metallurgy, his distinguished service to education, his unstinted labors as editor of *Revue de Metallurgie*, and his important part in forming the Societe Francaise de Metallurgie, of which he is currently president. Born in Paris in 1880, educated as an engineer and practicing his profession, he still serves as consultant for leading French metallurgical companies. For many years he has been professor of metallurgy at his alma mater, Ecole Central des Arts et Manufactures. His specialty (if specialty there is in so many-sided a genius) has been in the transformations in the solid state and the techniques for their study.

Milton C. Parsons ⊜, formerly assistant professor of metallurgy at the Lawrence Institute of Technology, has accepted a position as materials engineer with the Burroughs Adding Machine Co., Detroit.

Robert K. LeRouax ⊜, who has been with the Oil Center Tool Co., Houston, Tex., since 1946, has been named chief engineer.

Robert B. Day ⊜ has been transferred from the Linde Air Products Co., New York City, to the metallurgical division of the Oak Ridge National Laboratory, Oak Ridge, Tenn.

Oliver H. Cook ⊜, who graduated from Rensselaer Polytechnic Institute in January 1950, is now employed as a metallurgist at the Walworth Co., Boston, Mass.

George McMeans

Kaiser Steel Corp. has announced the promotion of **George B. McMeans** ⊜ to be works manager of its plant in Fontana, Calif. Mr. McMeans started his career in the steel industry by working for the Allegheny Steel Co. during summer vacations while attending Lehigh University. After graduation, he went to work at the John A. Roebling's Sons Co. steel mill, where he rose rapidly, becoming superintendent of the open-hearth and hot mills division in 1942. In 1947, on the crest of the western expansion of the steel industry, McMeans joined Kaiser Steel as assistant superintendent. In 1948, he was promoted to general superintendent.

George W. P. Rengstorff ⊜, who recently received his Sc.D. from Massachusetts Institute of Technology, is now employed as a research engineer at Battelle Memorial Institute, Columbus, Ohio.

William C. Wick ⊜, formerly associate metallurgist at Armour Research Foundation, is now foundry superintendent with the Rolle Mfg. Co., Inc., Lansdale, Pa.

Robert W. Graham ⊜ has recently been appointed general superintendent of the Duquesne works, Carnegie-Illinois Steel Corp.

Sharonsteel Products Co., Dearborn, Mich., announces that **Frank W. McLain** ⊜ has been appointed manager and **Edward A. Perrin** ⊜ has been appointed assistant manager.

Walter Bonsack

Walter Bonsack ⊜ has recently been appointed vice-president and director of research of the Christiansen Corp., Chicago. He was previously director of laboratories with the Apex Smelting Co., Chicago and Cleveland. Mr. Bonsack was born and educated in Germany, coming to this country in 1927. Since he is an authority on light metals and also experienced in the foundry field, he was elected to serve as chairman of the aluminum and magnesium division of the American Foundrymen's Society. Mr. Bonsack is the author of numerous papers and holds a a number of patents in this country and abroad on aluminum alloys, their heat treatment, fluxes and fluxing processes, special melting furnaces and refining methods. At the Christiansen Corp., he will be in charge of an extensive aluminum research program.

M. Hansen ⊜ has been appointed supervisor of nonferrous metals research of Armour Research Foundation of Illinois Institute of Technology. He was previously senior metallurgist.

Vladimir A. Grodsky ⊜ has retired from the position of metallurgist at the U. S. Naval Gun Factory and has been appointed consultant with the U. S. Bureau of Mines.

Pittsburgh Metallurgical Co., Inc., announces the appointment of **Thomas C. Ford** ⊜ as district manager of the Cleveland area.

Personals

A. H. Koch, sales manager of standard industrial equipment of Surface Combustion Corp., Toledo, Ohio, and **W. A. Darrah**, president of the Continental Industrial Engineers, Inc., Chicago, were recently elected to the industrial and commercial Hall of Flame of the American Gas Assoc.

Thomas J. Moore, Jr., is now vice-president and general manager of Brainard Steel Co., Warren, Ohio.

Armco Steel Corp. announces the appointment of **S. P. Watkins** and **P. B. Kline** as manager and assistant manager, respectively, of stainless bar and wire sales at the Middletown, Ohio, plant. Mr. Watkins has been with Armco since 1931 and, after advancing through various sales positions, in 1949 he was appointed assistant to the general manager at Baltimore, Md. Mr. Kline started with Rustless Iron Co. as salesman in 1937. Shortly after the merger of Rustless with Armco he was appointed assistant manager of bar and wire sales at Baltimore.

Russell J. Haigis has been appointed chief chemist and metallurgist in charge of the laboratories at the Stanley Works, New Britain, Conn.

J. Allison, formerly of A. C. Geldner & Co., has been appointed sales representative for the states of Oregon and Washington by Titan Metal Mfg. Co., Bellefonte, Pa.

James A. Harding has been appointed factory manager of Modernair Corp., Oakland, Calif. He was formerly project engineer with Schlage Lock Co., San Francisco, Calif., and manufacturing engineer with Marchant Calculating Machine Co., Oakland, Calif.

R. L. Shannon has been promoted to manager of the metal industries department of the Diversey Corp., Chicago. He joined the department six years ago, having been advanced to the position of supervisor and manager of the entire Chicago sales territory prior to his present appointment.

Carnegie Institute of Technology announces that **Roman Smoluchowski** has been promoted to professor of metallurgical engineering. He came to Carnegie Tech in 1946 and was previously a research physicist with the laboratory of General Electric Co.

H. B. Osborn, Jr., technical director of Ohio Crankshaft Co., has been elected president of the Cleveland Technical Societies Council.

G. L. Root has been transferred by Reynolds Metals Co. from technical service engineer in Cleveland to head of foil sales in western Pennsylvania, with headquarters in Pittsburgh, Pa.

Harold Margolin, formerly a graduate student at Yale University, is now a research assistant at New York University.

Gerard F. McGinnis, who graduated from the University of Notre Dame in January 1950, has accepted a position as assistant metallurgist with Chevrolet-Detroit Forge Gear & Axle Co.

J. P. Hansen has recently joined the Southern States Equipment Corp., Hampton, Ga. He was previously with Jackson & Moreland, Engineers, and the Draper Corp.

Following graduation from the University of Illinois in February 1950, **Stuart L. Rice** has been appointed an assistant metallurgist for the Atchison, Topeka & Santa Fe RR. at Topeka, Kan.

Personals

Gould Storage Battery Corp., Trenton, N.J., announces the appointment of **F. A. Miller** ● as northeast regional manager (northern New Jersey, eastern New York and New England). He was formerly New York district manager.

Frank J. Stanley ●, formerly works manager of Farrell-Cheek Steel Co., is now works manager of McConway & Torley Corp., Pittsburgh, Pa.

George N. Vitt ●, formerly general sales manager and technical consultant of the Airex Div. of the Lionel Corp., has accepted a position as editor of the *American Exporter Industrial*, a publication for reporting engineering and technical developments to foreign fields. His office is in New York City.

Charles C. Cooper ●, a recent graduate of the University of Pittsburgh, has accepted a position as process engineer in the metallurgical department of the Edgar Thomson Works of the Carnegie-Illinois Steel Corp., Braddock, Pa.

Electro Metallurgical Div., Union Carbide and Carbon Corp. announces that **W. H. Ferguson** ● has been promoted from sales representative in the New York area to head sales of the company in the eastern seaboard and Birmingham areas.

Orrin E. Andrus ●, vice-chairman of the Los Angeles Chapter of the American Society for Metals and recently director of the service and development laboratory of the A. O. Smith Corp., Los Angeles, has been transferred to the home office in Milwaukee, Wis., to the position of manager of research laboratories. He has been with A. O. Smith Corp. for 25 years.

Roland J. Ahern ●, president and general manager of the Billings and Spencer Co., was elected a member of the board of directors of the Bingham-Herbrand Corp., of Toledo and Fremont, Ohio, of which his company is a subsidiary.

Horizons, Inc., Cleveland, Ohio, and Princeton, N. J., announces that **Jacob Louis Snoek,** noted Dutch scientist, has joined its physics department staff. Dr. Snoek's field is chiefly that of magnetism.

After graduation from Lehigh University in February 1950, **John J. Blazejewski** ● was employed by Ferro Machine & Foundry, Inc., Cleveland, as a supervisory trainee in the melting department.

Leslie E. Guilford ● has been transferred from metallurgist at the U. S. Naval Shipyard, Portsmouth, N. H., to scientific staff assistant at the sound division of the U. S. Naval Research Laboratory, Washington, D.C.

Richard L. Hoff ●, formerly with Western Cartridge Co., is now metallurgist at the Naval Air Experimental Station, Naval Air Material Center, Philadelphia, Pa.

Linn H. Galeener ● is now superintendent of the directional drilling department of the Houston (Tex.) Oilfield Material Co., Inc.

Gus Scarvelis ● is now with the rock bit division of Timken Roller Bearing Co., Mount Vernon, Ohio.

F. R. Meyer, III, ● is now manager of the commercial research department of Acme Steel Co., Chicago.

Roy D. Haworth, Jr., ● has been appointed manager of product development of the carbide alloys division of Allegheny Ludlum Steel Corp. and will be located in Detroit. He was formerly supervisor of abrasion research, Armour Research Foundation.

Grain Size Effect in Creep of Austenite*

THE high-temperature strength of complex alloys such as those based on the iron-chromium-nickel system is determined by many factors. Among these factors the following three are especially interrelated and are difficult to study separately: *(a)* grain size, *(b)* extent of alloying of the solid solution, and *(c)* dispersion hardening. This paper describes two methods of separately evaluating the influence of grain size on creep strength.

When the grain size of an alloy such as 20-14 Cr-Ni steel is coarsened by heating to a high temperature, the dispersion hardening tendency is changed. A method of producing different "inherent" grain sizes with identical dispersion hardening tendencies is to use different degrees of reduction in the hot working of the ingots but with the same heating schedules. The compositions and grain sizes of two wrought 20-14 steels produced in this manner and having the same dispersion-hardening tendency were as follows:

Fine-Grained 20-14 — 0.16% C, 19.6% Cr, 14.2% Ni, 2.4% Si, grain size No. 7.

Coarse-Grained 20-14 — 0.17% C, 19.05% Cr, 14.0% Ni, 2.4% Si, grain size No. 3.

The creep curves for these two steels at 1290° F. and 5700 psi. are shown in Fig. 1. Under these conditions the total creep was 0.0049 in. for the fine-grained steel and 0.0004 in. for the coarse-grained steel. Creep rate was zero for the coarse-grained steel after about 3 hr.; for the fine-grained specimens the rate was 0.0103% per hr. between 24 and 48 hr., and 0.0020 between 72 and 96 hr. Short-time tensile properties at 1290° F. were as follows:

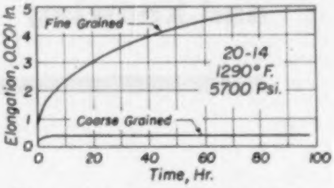


Fig. 1 — Creep of Fine-Grained and Coarse-Grained 20-14 Cr-Ni Steels at 1290° F.

	Y.S.	T.S.	Elong.	R.A.
Fine	29,800	42,600	25%	63%
Coarse	25,300	48,600	16	30

It would be desirable to eliminate completely any effect of dispersion hardening while investigating the effect of grain size on high-temperature strength. The following means of achieving this result was devised: A 14-14 Cr-Ni steel (A) was completely spheroidized in the fine-grained condition by annealing at 1560° F., and the chemical composition of the solid solution remaining was determined. A second

Table I — Compositions of Steels A and B

	C	Ni	Cr	W	Mo	G.S.
A	0.5	15.0	14.3	2.25	0.50	7-8
A_1	0.5	15.0	13.6	2.1	0.30	2-3
A_2	0.1	15.0	9.6	1.55	0.20	7-8
B	0.05	14.0	10.0	1.48	0.26	—

"A" represents total composition of steel A; A_1, the solid solution after quenching from 2370° F.; A_2, the solid solution after annealing at 1560° F.; B, the total composition of steel B.

(Continued on p. 800)

*Abstract from "Grain Size of High-Alloy Austenite as a Factor in Its High-Temperature Strength", by A. M. Borzdyka, *Izvestiya Akademii Nauk S.S.S.R., Otdelenie Khimicheskikh Nauk*, 1949, p. 121-127.

Grain Size and Creep

(Starts on p. 798)

steel (B) was made to have a composition the same as this solid solution. Chemical analysis data for these two steels are given in Table I. Specimens of both steels were heat treated to have various grain sizes in the range 2 to 8. Suitable tests showed that steel B was not subject to dispersion hardening.

The results of creep tests on steels A and B are shown in Fig. 2

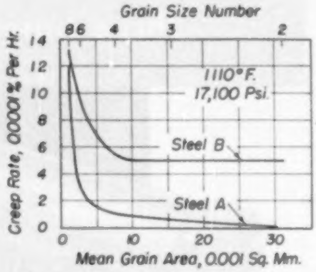


Fig. 2 — Effect of Grain Size on Creep Rate of Steels A and B at 1110° F.

in the form of a plot of creep rate versus grain size. The following conclusions were drawn from these curves:

1. As steel A was in the completely spheroidized condition for grain size No. 8, it is evident that the presence of spheroidized carbides has little effect on creep strength; steels A and B have about the same strength at this grain size.

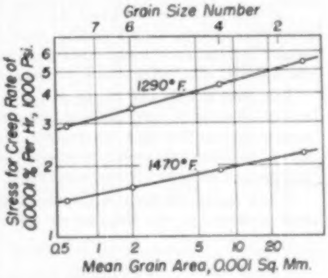
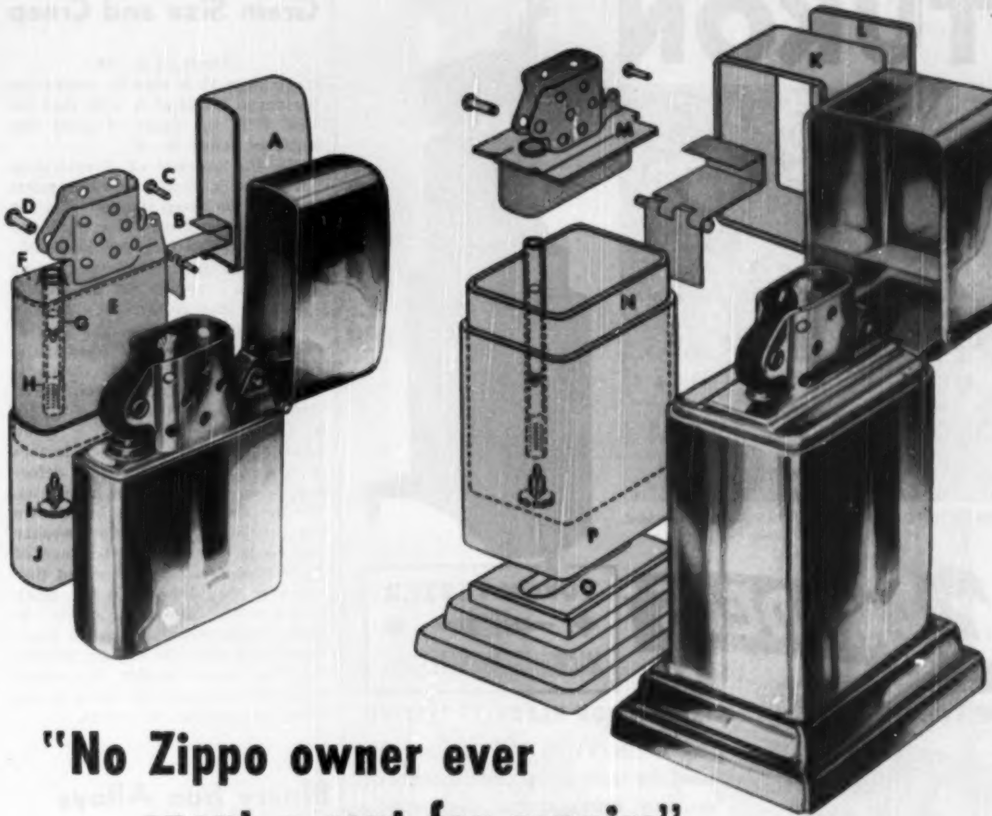


Fig. 3 — Logarithmic Dependence of Creep Strength on Grain Size in 60-20 Nichrome

2. The strengthening effect of coarser grain size when dispersion hardening effects are excluded is shown by the curve for steel B.

3. The important part played by dispersion hardening in increasing

(Continued on p. 802)



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POCKET LIGHTER A and J, top and bottom of outside case, deep drawn from brass strip. B, nickel silver hinge and pin. C, solid brass cam rivet. D, tubular brass rivet for flint wheel. E, nickel silver inner shell and chimney. F, nickel silver top plate. G, brass flint follower. H, seamless brass flint tube. I, brass flint tube screw.

TABLE LIGHTER K and P, special shape seamless brass tube for top and bottom outside case. L, brass top plate. M, brass chimney seal plate. N, special shape seamless brass tube, telescopic fit. O, die pressed brass forging. Chimney unit and its components are the same as the pocket lighter. Both lighters are finished in gleaming chromium plate.

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Grain Size and Creep

(Starts on p. 798)

creep strength is seen by comparing the curve for steel A with that for steel B in the range of grain size numbers below No. 8.

In the absence of dispersion hardening a simple relation exists between the creep strength and the average grain area. This is shown by the log-log plot for 60-20 Nichrome in Fig. 3. In alloys showing dispersion hardening the corresponding plot results in a broken curve instead of a straight line.

The equicohesive temperature concept of Jeffries and Archer is objected to on two counts. First, the equicohesive temperature is not a fixed temperature for a given alloy but depends on many factors such as grain size, rate of deformation and dispersion hardening. Second, since the grain boundaries are disordered and therefore weaker regions in the crystal structure of the metal, it is to be expected that cracking would begin at the grain boundaries at all temperatures. At lower temperatures, when the grain boundaries are only slightly weaker than the grain proper, the crack may follow through the grain as the result of geometrical factors.

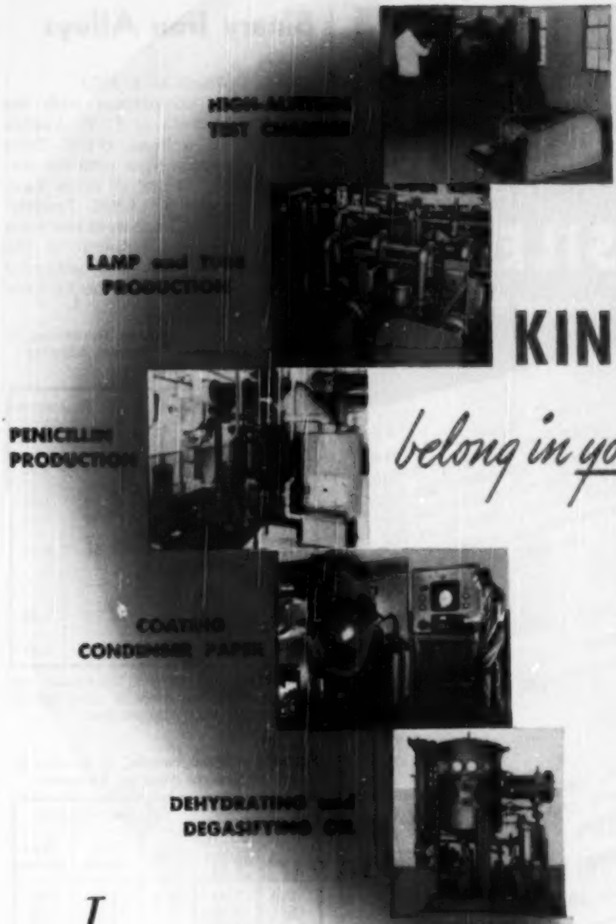
Binary Iron Alloys*

THE purpose of this study was to determine the influence of alloying elements dissolved in ferrite on its hardness, work hardening, and softening during heating. An induction furnace was used to melt a 44-lb. heat of each alloy, in which Armco iron was the base metal. The maximum impurity contents were 0.04% C, 0.06% Mn, 0.035% S, 0.020% P, 0.25% Ni, and traces of silicon, chromium and copper. Specimens for cold rolling 60 x 10 x 10 mm. (2.36 x 0.39 x 0.39 in.) were prepared from forged bars of each alloy. Hardness measurements were made using a Vickers tester with a 10-kg. load.

To determine the hardness of the ferrites in the equilibrium condition, the alloys were annealed at 1790° F. for 15 hr. and then cooled to 750° F. at 18° F. per hr. The ferrite hardness produced by 1% by weight of each alloying element is shown in

(Continued on p. 804)

*Abstract from "The Hardening and Softening of Binary Alloys of Iron", by M. M. Shteinberg, *Stal*, Vol. 7, 1947, p. 1107-1110.



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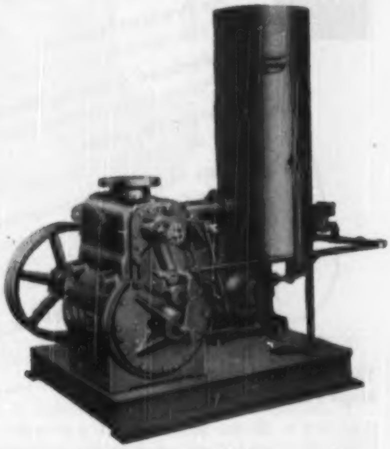

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Binary Iron Alloys

(Starts on p. 802)

Table I, in comparison with the analogous data of C. R. Austin (A.S.M. *Transactions*, 1943). Table II shows comparisons with the tensile strength values of C. E. Lacy and M. Gensamer (A.S.M. *Transactions*, 1944). The apparent low value of hardness and strength of the chromium alloy has been attributed to aging effects in the iron by Lacy

Table I — Solid Solution Hardening of Ferrite by 1% of Several Alloying Elements

Alloy Element	Shteinberg		C. R. Austin	
	V.P.H.	Ratio	V.P.H.	Ratio
(Fe)	80	1.00	64	1.00
Cr	74	0.93	62	0.97
Mo	85	1.06	102	1.59
Co	88	1.10	79	1.23
V	93	1.16	—	—
Ni	94	1.17	84	1.31
Al	96	1.20	—	—
W	98	1.22	—	—
Cb	100	1.25	—	—
Mn	105	1.31	83	1.30
Ti	(125)	1.56	—	—
Si	128	1.60	121	1.89

V.P.H. is the Vickers hardness; the ratio given is hardness of alloy ferrite to hardness of unalloyed iron.

Table II — Strengthening of Ferrite by 1% of Several Alloying Elements

	S'berg V.P.H. Ratio	Lacy & Gensamer		
		T.S.	T.S. Ratio	Corrected
(Fe)	1.00	33.9	1.00	1.05
Cr	0.93	33.7	0.99	1.04
Mo	1.06	38.5	1.13	1.19
Co	1.10	34.6	1.02	1.07
V	1.16	35.8	1.05	1.11
Ni	1.17	39.0	1.15	1.21
Al	1.20	40.4	1.19	1.25
W	1.22	36.1	1.06	1.12
Cb	1.25	—	—	—
Mn	1.31	(41.0)	1.21	1.27
Ti	1.56	48.5	1.43	1.50
Si	1.60	51.3	1.51	1.59

First column is Shteinberg's hardness ratio from Table I. Other columns (from Lacy and Gensamer) are tensile strength in 1000 psi., ratio to unalloyed iron, and ratio corrected for aging.

and Gensamer. Their correction for this factor is shown in the last column of Table II.

The strain hardening behavior of the alloys was determined by hardness measurements on specimens cold rolled up to 90% reduction. The course of hardness increase was found to be essentially the same for both unalloyed and alloyed ferrite, in fair agreement with the

(Continued on p. 806)

Binary Iron Alloys

(Starts on p. 802)

results of C. R. Austin, L. A. Luini and R. W. Lindsay (A.S.M. *Transactions*, 1945).

The resistance to softening of the 90% cold worked alloys was determined in two ways: First, by heating a cold worked specimen at 750° F. in a lead bath for 1 hr., cooling to 660° F. at 35° F. per hr., and then air cooling. (After hardness testing, the same specimen was carried through the same cycle for holding temperatures increased successively by 90° F. up to a maximum of 1290° F.) Second, the course of softening with increasing time at 1020, 1110, and 1200° F. was determined, generally for times up to 1 hr. As a rough measure of the effectiveness of a given alloy content in preventing softening, the quantity, $\Delta H_t - \Delta H_f$, was proposed, where ΔH_t is the difference in hardness between alloyed and unalloyed iron after heating for 1 hr. at a given temperature, and ΔH_f is the corresponding difference in hardness after annealing.

For those alloys that showed significant retardation of softening, the maximum value of $\Delta H_t - \Delta H_f$ occurred at 1020° F. For comparison, the corresponding quantity was calculated from the data of Austin, Luini and Lindsay and is also given in Table III.

Table III — Effectiveness of Elements in Preventing Softening of Ferrite

	Shteinberg		C. R. Austin	
	% Added	Max. Effect	% Added	Max. Effect
Mo	0.32	137	0.54	141
Cb	0.32	110	—	—
W	0.54	100	—	—
Co	3.92	53	5.08	100
Cr	4.6	50	4.83	88
Cu	0.44	47	—	—
Al	1.03	35	—	—
Mn	1.76	20	1.30	130
Si	1.88	17	1.21	87
Ni	3.97	−20	4.83	−13

The maximum effect is in terms of $\Delta H_t - \Delta H_f$, as defined in the text.

Shteinberg concluded that the elements that produce greatest solid solution hardening (silicon, titanium and manganese) are different from the elements that most effectively prevent softening (molybdenum, columbium and tungsten). This conclusion is not supported by Austin's results, which show molybdenum to be effective for both purposes.

A. G. Guy

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Multi-Arc Welding of Thin Sheet*

THE welding of very thin sheet metal (less than 0.05 in.) using the metal-arc process offers some difficulties which it is claimed are eliminated by using the multiple-arc welding method described by the author. This method utilizes a combination of the twin-carbon arc and the metal-arc processes with very low welding currents (7 to 25 amp. in the metal-arc circuit, 12 to 40 amp. in the carbon-arc circuit) and small electrodes (metal $\frac{3}{64}$ to $\frac{1}{16}$ in. and carbon ⅛ to ¼ in.). This method is claimed to be particularly suited to welding thin sheet metal

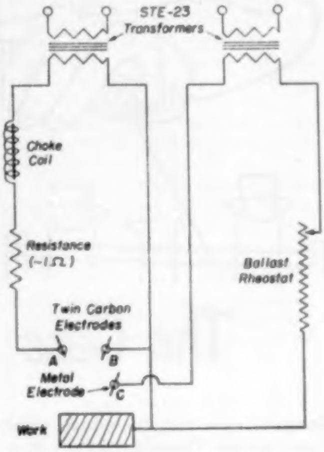

Fig. 1 — Welding Power Circuit for Multiple-Arc Welding

because heating of the electrode can be controlled independently of the heating of the work.

The welding power circuit is illustrated by Fig. 1. In this figure the twin carbon electrodes are shown by *A* and *B*, electrode *A* being fixed in the holder and electrode *B* adjustable. A transformer of the STE-23 type furnishes current to the carbon electrodes through a choke coil and a series resistance of the order of one ohm. The movable electrode *B* is grounded to the work. For arc stability, an oscillator is connected to the welding circuit or the current may be supplied from a transformer of the PS-100 type with

(Continued on p. 810)

*Abstract from "Multiple-Arc Welding", by K. V. Zvegintseva, *Avtogennoe Delo*, Vol. 20, 1949, No. 7.

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Multi-Arc Welding

(Starts on p. 808)

a frequency of 490 cycles per sec.

A second STE-23 transformer supplies current to the metal electrode *C* through a ballast rheostat. Thus the two sources of welding current permit adjustment of the current in the metal arc independently of the adjustment of current in the carbon arc.

A lightweight holder is used for the metal electrode but the carbon electrodes are mounted in a special

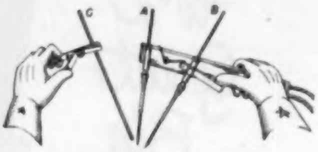

Fig. 2 — Manual Control of the Three Electrodes in Multiple-Arc Welding

holder such that electrode *A* is fixed in position whereas electrode *B* can be rotated on a pivot by the operator's thumb against a tension spring (Fig. 2). An angle of approximately 30° is maintained between the carbon electrodes during welding. It is claimed that five arcs are formed as shown in Fig. 3.

The carbon arc is struck by touching *A* and *B* together, then separating them, and holding a relatively low-current arc. A high

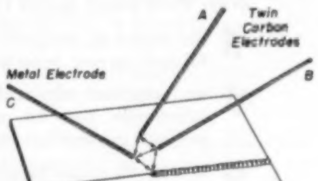

Fig. 3 — Five Arcs Are Formed in Multiple-Arc Welding

current density at the cathode is stated to be of the order of 1000 amp. per sq.cm. (6500 amp. per sq.in.) and about 5 sec. after the arc flame has been brought near the work an arc is established between the fixed electrode *A* and the work. As the temperature of the work rises this a-c. arc becomes more stable.

Most favorable conditions for welding 18-8 Cr-Ni stainless steel (0.02 to 0.04 in. thick) with UONI-13

(Continued on p. 814)

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SILVALOY 20	20%	1430°F	1500°F
SILVALOY 35	35%	1125°F	1295°F
SILVALOY 40	40%	1135°F	1205°F
SILVALOY 45	45%	1125°F	1145°F
SILVALOY 50	50%	1160°F	1175°F

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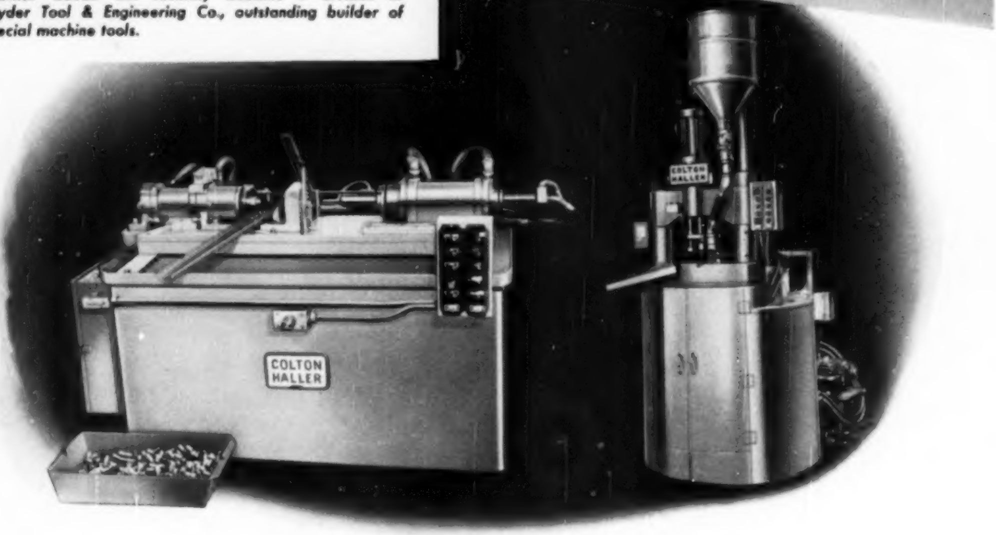

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Multi-Arc Welding

(Starts on p. 808)

metal electrodes were as shown in Table I.

Average values of the ratio of current in the carbon arc to current in the metal arc (I_C/I_M) for different thicknesses were as follows:

Sheet Thickness	Ratio (I_C/I_M)
0.039 in.	1.4
0.032	1.7
0.0197	1.9

Tensile properties of butt joints, with weld reinforcement not removed, in 0.032-in. titanium-stabilized 18-8 sheet were as follows:

	Base Metal		Welded Joint	
Test Temp.	Tensile	Elongation	Tensile	Elongation
Room	94,725	36.5%	89,180	34.5%
930°	64,000	12.5	57,890	10.9
1290	44,800	17.5	42,950	10.9
1560	25,600	17.5	30,440	9.5

Metallographic examination showed the weld metal to be free from cracks and porosity. Base metal grain size was 6 to 8 and that of the heat-affected zone 5 to 8. The weld metal was dendritic and of medium grain size. In the heat-affected zone a preponderance of current in the metal arc produced a coarser grain size than did a preponderance of current in the carbon arc; that is, with a low value of the ratio I_C/I_M, compared with a high value such as 2. There was no evidence of appreciable carbon pickup by either the weld metal or the heat-affected zone, and no loss of chromium, nickel or titanium was observed.

Table I—Most Favorable Conditions for Welding 18-8 Cr-Ni Stainless Steel

Sheet Thickness, In.	Size of Electrode, In.		Current, Amp.	
	Metal	Carbon	Metal	Carbon
0.039	0.059	0.24	19-20 22-23 23-24	38-36 30-28 24-23
0.032	0.039	0.16	11-12 13-14 14-15	25-24 22 20
0.0197	0.039	0.12	7-7.5 8-8.5	16-15 14-13

Welding speeds averaged about as follows:

Sheet Thickness	Speed
0.0394 in.	7.41 in./min.
0.0315	7.54
0.0197	6.76

For material of constant thickness the welding speed decreases

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Multi-Arc Welding

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with decreasing ratio of I_C/I_M as shown by Fig. 4.

Advantages claimed for this multiple-arc method over the atomic hydrogen, oxy-acetylene and metal-arc processes for welding very thin sheet metal are as follows: *(a)* The metal-arc may be established with currents as low as 6 amp., *(b)* the ratio of currents in the two arc circuits may be varied during welding so that heating of the work is easily controlled, *(c)* the contour of the weld surface is smoother, and *(d)* bead size and the amount of penetration can be regulated by varying the current ratio, I_C/I_M.

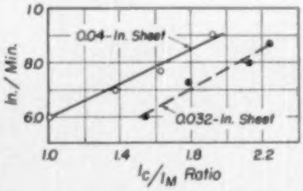

Fig. 4 — Relation Between Welding Speed and Ratio of Currents in Carbon and Metal Electrode Circuits (I_C/I_M)

Magnetic Test for Hardenability*

To determine one of the most important characteristics of steel — its hardenability — it is necessary to know the depth of penetration of the martensitic zone in the hardened steel. Hardenability can be expressed as the ratio of the cross section of the martensitic case, S_M, to that of the unhardened core, S_C. If the depth of the hardened zone is $\delta = R - r$ (where R is the radius of the cylindrical specimen and r is the radius of the unhardened core), then hardenability can be characterized by the quantity

$$\frac{S_M}{S_C} = \frac{\delta\,(2R - \delta)}{(R - \delta)^2} \qquad (1)$$

or its reciprocal, S_C/S_M.

The depth of hardening can be determined by microscopic study of a section cut from a quenched

(Continued on p. 818)

*Verbatim extracts from "Determination of the Depth of Penetration of the Martensitic Zone in Hardened Steels by a Magnetic Method", by M. V. Dekhtyar, *Zhurnal Teckhnicheskoi Fiziki*, Vol. 19, 1949, p. 1397-1407.

Hardenability Test

(Starts on p. 816)

bar or by a hardness traverse across such a section. A simpler method is that of "face quenching" proposed by Gudtsov and Selnitski in 1946, which eliminates the necessity for sectioning the hardened specimen. In this test the hardenability is determined from the curve of hardness values measured along the length of a cylindrical specimen. [In this country the end quench method of hardenability testing is credited to W. E. Jominy and A. L. Boegehold, A.S.M. *Transactions*, 1938.] While emphasizing the advantage of the method of "face quenching", several authors have pointed out that the martensite transformation in the core of a specimen takes place in the presence of significant internal stresses, and that this condition does not exist in "face quenching". Therefore, the results of investigations of hardenability by this method might differ from the actual hardenability of the steel. Also, the applicability of this method is limited to carbon and low-alloy steels.

We [the author] wish to point out a general characteristic of all methods used at present to determine hardenability — namely, that they are carried out on laboratory specimens and not on production parts. Also, present methods require destruction of the specimen to determine the depth of hardening. The magnetic method does not suffer from these limitations.

It is known that the coercive force of a homogeneous ferromagnetic material determined for the condition $I_r = 0$ or $\phi_r = 0$ is independent of the cross-sectional area of the specimen and is a physical characteristic of the material. [ϕ represents the magnetic flux and I the flux density.] However, under identical heat treatments, the coercive force of specimens with small cross-sectional area was found to be higher than that of larger specimens. Therefore it was proposed that the observed decrease of coercive force for the larger specimen was the result of the slower cooling rate in the interior layers and of the formation of troostite in the core of the specimen. Mikheev has determined the dependence of the coercive force of ferromagnetic materials on the thickness of a carburized layer.

Specimens incompletely hardened act like two-layer ferromag-

(Continued on p. 822)

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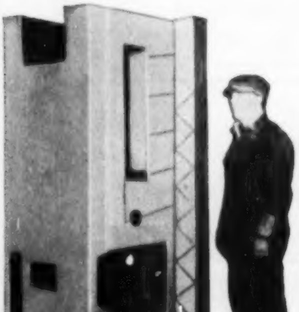

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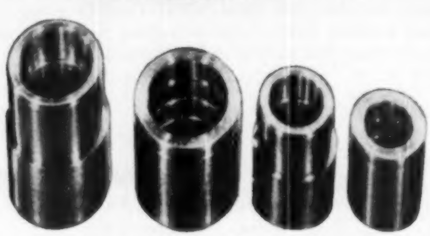

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Hardenability Test

(Starts on p. 816)

netic materials with a martensitic surface and a soft core. The theory of the coercive force of such two-layer materials is the basis of the proposed magnetic method for determining depth of hardened layer. In contrast to a specimen of homogeneous cross section, a two-layer cylinder under the conditions $I_r = 0$ or $\phi_r = 0$ requires a demagnetizing field H_p that depends on the geometry of the layers corresponding to the martensitic shell and the soft core.

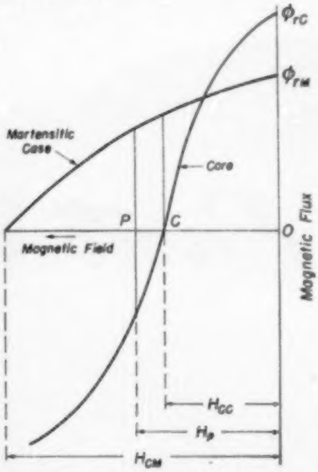


Fig. 1 — Schematic Illustration of the Relation Between Demagnetization Curves of the Core Material and the Martensitic Case. ϕ_{rC} and ϕ_{rM} are the residual magnetic flux values of core and martensitic case, while H_{CC} and H_{CM} are coercive force values

Let the demagnetizing field for a fully martensitic cylinder be H_{CM}, and for an unhardened cylinder be H_{CC}. Since $H_{CM} > H_{CC}$, during demagnetization the core is demagnetized before the martensitic shell. On further increase in the demagnetizing field the direction of magnetization in the core is reversed. At some field strength $H_p (H_{CC} < H_p < H_{CM})$ the I_r of the cylinder is equal to zero, but the individual I_r of each of the two layers is not equal to zero. This field, H_p, is determined by the condition $I_r = 0$ or $\phi_r = 0$ and is the demagnetization field of the complete two-layer cylinder, $H_p = H_{CC} + \Delta H$ (Fig. 1). If, in the measurement of the magnitude of H_p, a condition of linear dependence of

(Continued on p. 824)

Hardenability Test

(Starts on p. 816)

magnetic flux ϕ on the demagnetizing field H_p is realized, then the magnitude of the latter can be calculated using the formula

$$H_p = H_{CC} + \Delta H$$

$$= H_{CC} + \frac{H_{CM} - H_{CC}}{\frac{I_{rC}}{I_{rM}} \frac{S_C}{S_M} \frac{H_{CM}}{H_{CC}} + 1} \qquad (2)$$

Since $H_p = k\,J_p$ (where k is a constant of the coil and J_p is the demagnetizing current), $H_{CM} = k\,J_{CM}$ and $H_{CC} = k\,J_{CC}$, then

$$J_p = J_{CC} + \Delta J$$

$$= J_{CC} + \frac{J_{CM} - J_{CC}}{\frac{I_{rC}}{I_{rM}} \frac{S_C}{S_M} \frac{J_{CM}}{J_{CC}} + 1} \qquad (3)$$

and the quantity that characterizes hardenability, S_C/S_M, is given by

$$\frac{S_C}{S_M} = \frac{H_{CM} - H_p}{(H_p - H_{CC})\,\frac{I_{rC}}{I_{rM}}\,\frac{H_{CM}}{H_{CC}}}$$

$$= \frac{J_{CM} - J_p}{(J_p - J_{CC})\,\frac{I_{rC}}{I_{rM}}\,\frac{J_{CM}}{J_{CC}}} \qquad (4)$$

where the quantities H_{CM}, H_{CC} (or the corresponding J_{CM}, J_{CC}) and I_{rC}/I_{rM} are constants for a given steel and are determined once. Later, in determining the quantity S_C/S_M for a specimen with any arbitrary depth of hardened case, δ, it is sufficient to measure only H_p (or J_p).

The values of H_{CM}, H_{CC} (or J_{CM}, J_{CC}), I_{rC}/I_{rM} and H_p, need not refer to a saturating magnetic cycle. It is necessary only that these quantities be determined for a cycle with the same maximum magnetizing field. The value of H_{CC} (J_{CC}) is determined on the unhardened specimen, and H_{CM} (J_{CM}) on the hardened specimen. The cross section of the latter is chosen so as to insure through hardening, which in this instance is considered as hardening to more than 50% martensite. The value of I_{rC}/I_{rM} is determined from the formula

$$\frac{I_{rC}}{I_{rM}} = \frac{H_{CM} - H_{CC} - \Delta H}{\Delta H\,\frac{S_C}{S_M}\,\frac{H_{CM}}{H_{CC}}}$$

$$= \frac{H_{CM} - H_p}{(H_p - H_{CC})\,\frac{S_C}{S_M}\,\frac{H_{CM}}{H_{CC}}}$$

(Continued on p. 826)

Hardenability Test

(Starts on p. 816)

$$= \frac{J_{CM} - J_p}{(J_p - J_{CC}) \dfrac{S_C}{S_M} \dfrac{J_{CM}}{J_{CC}}} \quad (5)$$

For this, one specimen is hardened so as to obtain an arbitrary depth of hardened layer. Like H_{CM} and H_{CC}, the value of H_p (J_p) is measured using a magnetometric coercive force meter. Then the specimen is sectioned, the depth δ of hardened layer is determined microscopically, and S_C/S_M is calculated from Eq. 1. Having substituted the values of H_p, H_{CM}, H_{CC} (or J_p, J_{CM}, J_{CC}) and S_C/S_M in Eq. 3, one can calculate the quantity I_{rC}/I_{rM}.

Table I shows that the quantity I_{rC}/I_{rM} remains constant with an increase in S_C/S_M. [Two similar tables for other steels are not reproduced here.] This makes it possible to determine I_{rC}/I_{rM} on one specimen quenched so as to obtain an arbitrary depth of hardened layer. The value of I_{rC}/I_{rM} is necessarily obtained on a specimen of the same form and dimensions as the specimens to be tested later. The measurement of the demagnetizing field H_p (or J_p) may be carried out during normal cycles or during reverse cycles.

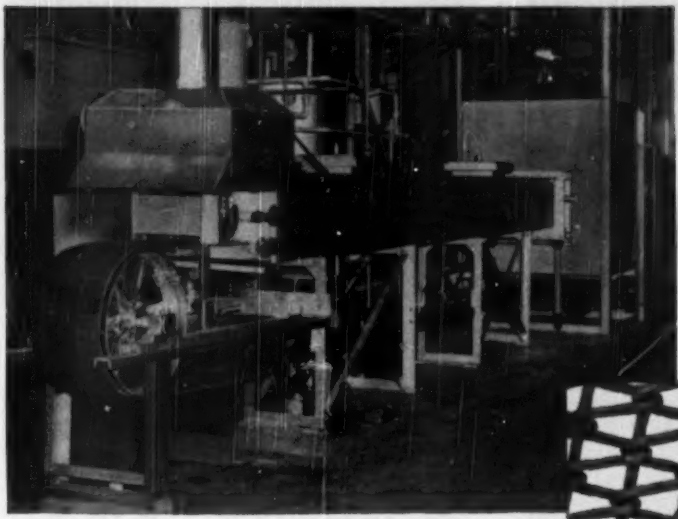
Table I — Experimental Data for 45-Mm. Diameter Specimens
(1% C, 1.5% Cr Steel)

No.	$\frac{S_C}{S_M}$	$\frac{I_{rC}}{I_{rM}}$	J_p
1	0	—	800 ma.
4	0.7	0.07	660
5	1.2	0.07	600
6	2.2	0.07	520
7	4.5	0.07	390
9	∞	—	145

S_C/S_M is the hardenability ratio (unhardened core to martensitic case), I_{rC}/I_{rM} is the ratio of residual magnetization values, and J_p is the demagnetizing current for the bar (in milliamperes). See also Fig. 2, p. 830.

In a uniform cylinder the demagnetizing field measured during a normal cycle of the hysteresis curve coincides with the value obtained on secondary demagnetization on direct reversal, if the reverse magnitude of the field corresponds to the condition $\varphi_{rM} = 0$, that is, to a field equal in coercive force to the martensitic case. For the two-layer cylinder the demag-

(Continued on p. 830)



Inconel conveyor belt installed in Electric Furnace Company continuous brazing furnace at the Beech Aircraft Corp., Wichita, Kansas. This WISSCO belt woven of Inconel was manufactured by the Wickwire Spencer Steel Division of the Colorado Fuel and Iron Corporation. It has served for two and a half years, operating at temperatures as high as 2040° F.

Close-up photograph of the woven Inconel conveyor belt after 22,368 hours of operation in high-temperatures brazing operations. Note that the belt is still in excellent condition.

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METAL PROGRESS

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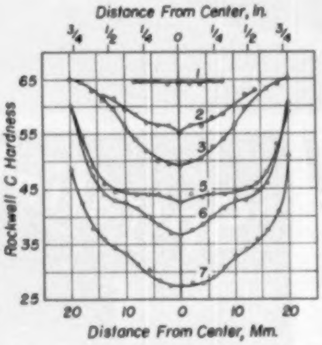
(a) Abstract; *(b)* Biography; *(c)* Correspondence; *(cp)* Critical Points; *(d)* Data Sheet; *(r)* Review.

Hardenability Test

(Starts on p. 816)

netizing field of a similar reverse cycle is less than the coercive force of the case. This circumstance serves as a criterion of the uniformity of hardening in the martensitic cylinder and therefore it can serve as a criterion of through hardening.

Although a test of the magnetic method for determining depth of martensitic case has been successful with induction hardened specimens, it is desirable to test it also using specimens heat treated in the conventional manner. The 50%



Sample No.	Sample Diameter	Demagnetizing Current, J_p
1	20 mm.	800 ma.
2	32	800
3	45	740
5	45	600
6	45	520
7	45	390

Fig. 2 — Hardness Distribution Curves and Demagnetizing Current Values, J_p, for Specimens of 1% C, 1.5% Cr Steel With Various Depths of Hardening

martensite zone will be taken as the separation of the martensitic layer and the unhardened core.

Steel specimens with different curves of hardness versus depth were obtained in the following manner: A number of identical specimens of each type of steel were heated about 35° F. above the transformation range. The first specimen was quenched as soon as its surface reached the furnace temperature, and the remaining specimens were quenched at 5-min. intervals. Hardness distribution curves after this treatment are shown in Fig. 2, for specimens of 1% C, 1.5% Cr steel 45 mm. (1.77 in.) in diameter and 200 mm. (7.88

(Continued on p. 834)

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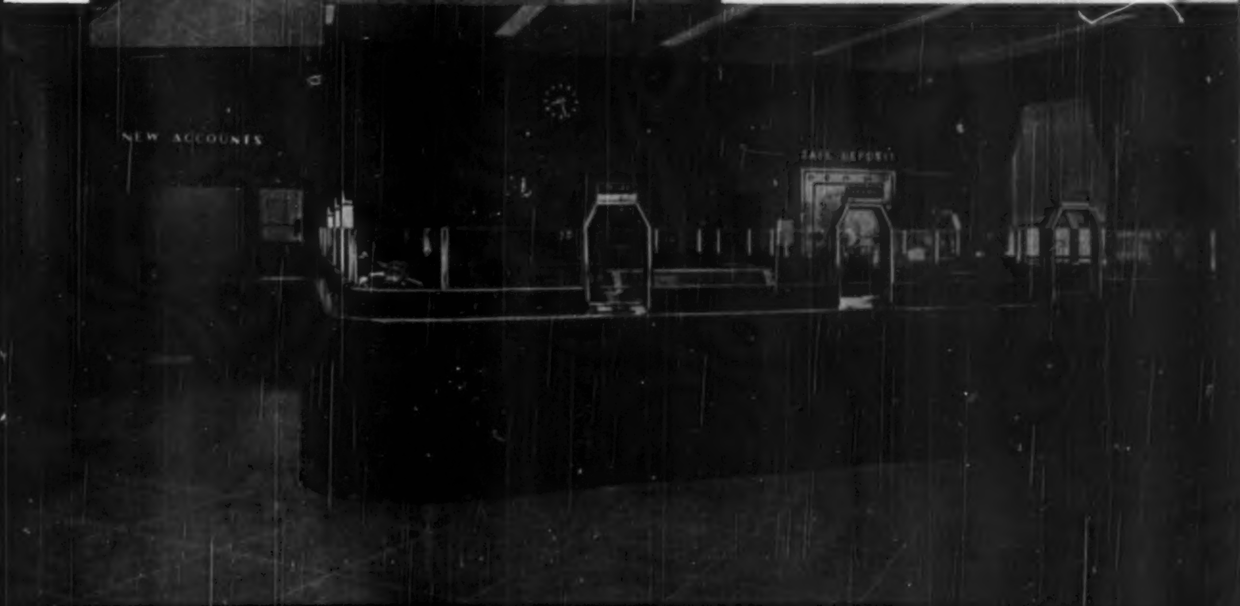

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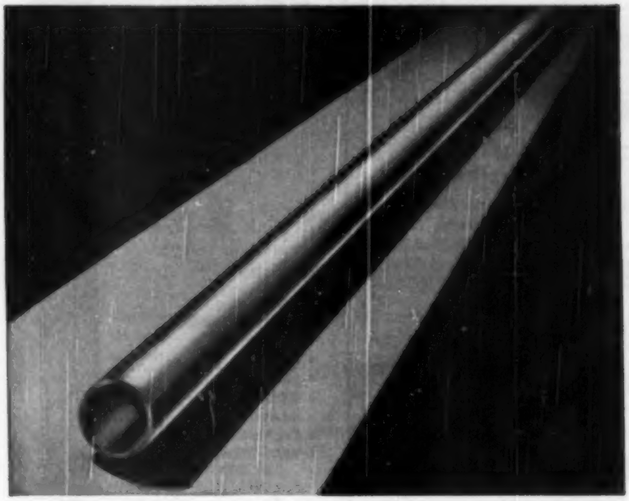

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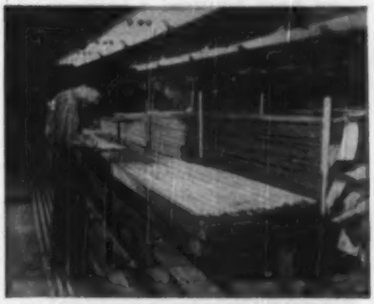

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Hardenability Test

(Starts on p. 816)

in.) long. In this figure are given also the hardness distribution curves for 20-mm. (0.79-in.) and 32-mm. (1.26-in.) diameter specimens, heat treated in the same way as the 45-mm. specimen No. 6. The center of the 32-mm. specimen contained more than 50% martensite.

On measuring these specimens in an open magnetic circuit, be-

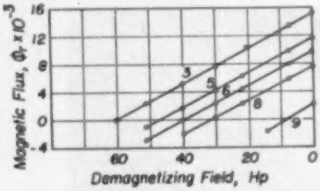

Fig. 3 — Experimental Curves Demonstrating the Linear Relation Between Demagnetizing Field, H_p, and the Residual Magnetic Flux, ϕ_r, for 45-Mm. (1.77-In.) Specimens of the 1% C, 1.5% Cr Steel

cause of the large demagnetizing factor ($\frac{1}{d} = 4.4$) there was a linear relation between the magnetic flux ϕ and the demagnetizing field H_p or J_p on demagnetization during normal cycles (Fig. 3). Therefore, using Eq. 2, the quantity S_C/S_M can be calculated from the value of the demagnetizing current J_p measured

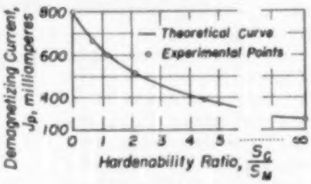

Fig. 4 — Comparison of the Theoretical and Experimental Values of S_C/S_M, the Ratio of Unhardened Core to Martensitic Case, for Specimens of the 1% C, 1.5% Cr Steel

for these specimens during normal cycles of the coercive force meter. Figure 4 compares the curve of J_p calculated by Eq. 3 and the experimental values of S_C/S_M from Table I corresponding to the given values of J_p. The values of S_C/S_M were determined by microscopic examination of the specimens at three diameters after sectioning.

Similar tests were made on specimens of this same steel 32 mm.

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Hardenability Test

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(1.26 in.) in diameter and 100 mm. (3.94 in.) long, and on specimens of carbon steel (about 0.65% C) with a rather high manganese content (about 0.75%) 30 mm. (1.18 in.) in diameter and 200 mm. (7.88 in.) long. Comparisons of theoretical curves with experimental values are shown in Fig. 5. [Tables and

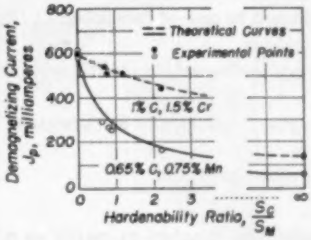

Fig. 5 — Comparison of the Experimental and Theoretical Values of S_C/S_M for 32-Mm. (1.26-In.) Specimens of the 1% C, 1.5% Cr Steel and for 30-Mm. (1.18-In.) Specimens of 0.65% C, 0.75% Mn Steel

graphs were given for each of these steels, but are omitted here because of their qualitative similarity to Table I and Fig. 2 and 3.]

When the proposed magnetic method is used for estimating the

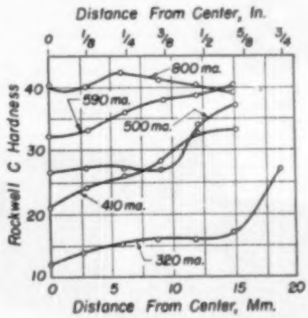

Fig. 6 — Hardness Distribution Curves and Demagnetizing Current Values, J_p, for Quenched Specimens of 0.4% C, 1% Cr Steel From a Production Run

hardenability of a series of finished pieces, it is unnecessary to calculate the value of S_C/S_M and therefore to measure the quantities H_{CM} (or J_{CM}), H_{CC} (or J_{CC}) and I_{rC}/I_{rM}. Considering the relation (Eq. 4) between the values of S_C/S_M and H_p (or J_p), it is possible to con-

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Hardenability Test

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struct a graph of S_C/S_M versus J_p from several pieces with different values of J_p for which the depth of hardening has been determined either microscopically or from hardness distribution curves.

Figure 6 gives hardness distribution curves and the corresponding values of J_p for five specimens of chromium steel (about 0.4% C and 1% Cr) 40 mm. (1.57 in.) in diameter which were chosen by magnetic measurements of J_p from a batch of production shafts after quenching.

The experimental data given in Fig. 2 and 6 [also three similar figures not reproduced here] show that the order of a series of specimens in regard to demagnetization corresponds to their order in regard to hardness distribution. The identity of distribution of each of the series of specimens investigated by us with regard to the value of J_p (or H_p) and with regard to the hardness distribution curve, permits carrying out tests using the value of J_p. The depth of penetration of the hardened zone may be judged from the J_p value without the necessity for cutting hardened specimens and determining hardness distribution curves.

[Twenty references are cited, of which the only one evidently not Russian is a 1945 translation of "The Influence of Alloying Elements on the Properties of Steel", by E. Bain, apparently a pirated edition of "Functions of the Alloying Elements in Steel", by Edgar C. Bain, A.S.M., 1939.]

Plasticity in Rolling*

METHODS for judging the plasticity of alloys include *(a)* the percentage elongation and reduction of area in a tension test, *(b)* the percentage reduction of height on the appearance of the first crack in "open" upsetting, *(c)* impact strength, *(d)* the degree of deformation when cracking begins in a torsion test, *(e)* Gubkin's plasticity diagram (Fig. 1), and *(f)* the wedge rolling method. The last method was devised by the author, and he shows its superiority over the other methods.

The wedge rolling test is carried out on either cast or wrought specimens of square or rectangular cross section. The specimen is rolled in rolls of constantly varying diameter so that reductions varying from 0 to more than 75% are obtained. The limit of plasticity is taken as the value of relative reduction of height, $U = \frac{H - h}{H}$, at which breaking begins. The first small cracks appear slightly below

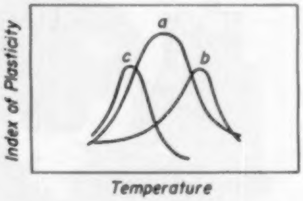

Fig. 1 — Typical Gubkin Plasticity Diagram. Curves (a) and (b) are the percentage reductions at which cracking first begins on slow and impact upsetting, respectively. Curve (c) is impact strength

*Abstract from "Estimation of the Plasticity of Metals and Alloys Suitable for Hot Rolling or Forging", by Yu. M. Chizhikov, *Zavodskaya Laboratoriya*, Vol. 40, 1949, p. 191-199.

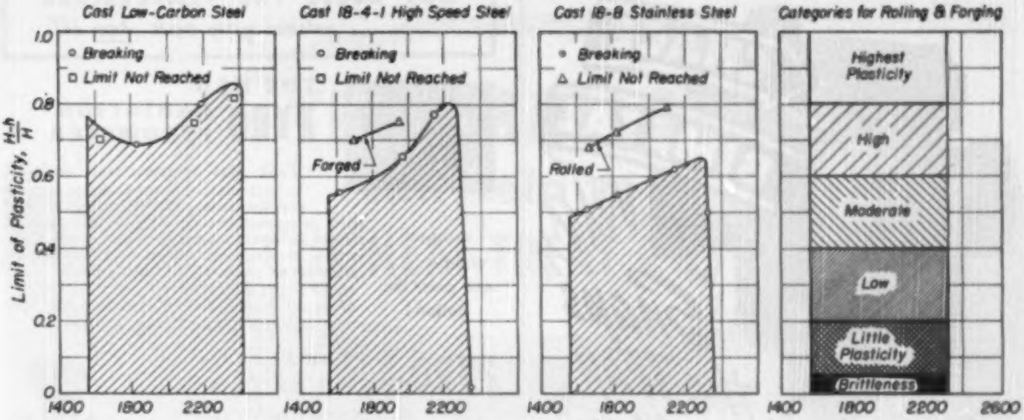

Fig. 2—Plasticity Diagrams by the Wedge Rolling Test

this limit. A plasticity diagram is obtained by plotting the limit of plasticity vs. temperature. Figure 2 shows the plasticity diagrams determined for three types of ferrous alloy. The best working temperature for cast low-carbon steel is 2370 to 1920° F. A cast highly alloyed chromium-nickel-molybdenum steel showed a constant decrease in the limit of plasticity from a value of $U = 0.6$ at 1560° F. to $U = 0$ at 2370° F. In comparison with the data shown in Fig. 2 for 18-4-1 and 18-8, hot twist test results gave 2140° F. as the optimum temperature for working the cast 18-4-1 steel and 2400° F. for cast 18-8. Thus, the hot twist test is not so useful as wedge rolling.

The right-hand diagram in Fig. 2 shows the categories of plasticity that are proposed on the basis of the wedge rolling test. In addition, it is suggested that alloys be classified as "plastically soft" if their plasticity increases with increasing temperature. The plasticity of "plastically hard" alloys decreases with increasing temperature.

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